WIND ENERGY TECHNOLOGIES OFFICE

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

U.S. Wind Industry Update

WindExchange Webinar

September 2016

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Lawrence Berkeley National Laboratory

2015 Wind Technologies Market Report

Purpose, Scope, and Data:

- Publicly available annual report summarizing key trends in the U.S. wind power market, with a focus on 2015
- Scope primarily includes wind turbines over 100 kW in size
- Separate DOE-funded report on distributed wind
- Data sources include AWEA, EIA, FERC, SEC, etc. *(see full report)*

Report Authors:

- Primary authors: Ryan Wiser and Mark Bolinger, Berkeley Lab
- Contributions from others at Berkeley Lab, Exeter Associates, NREL

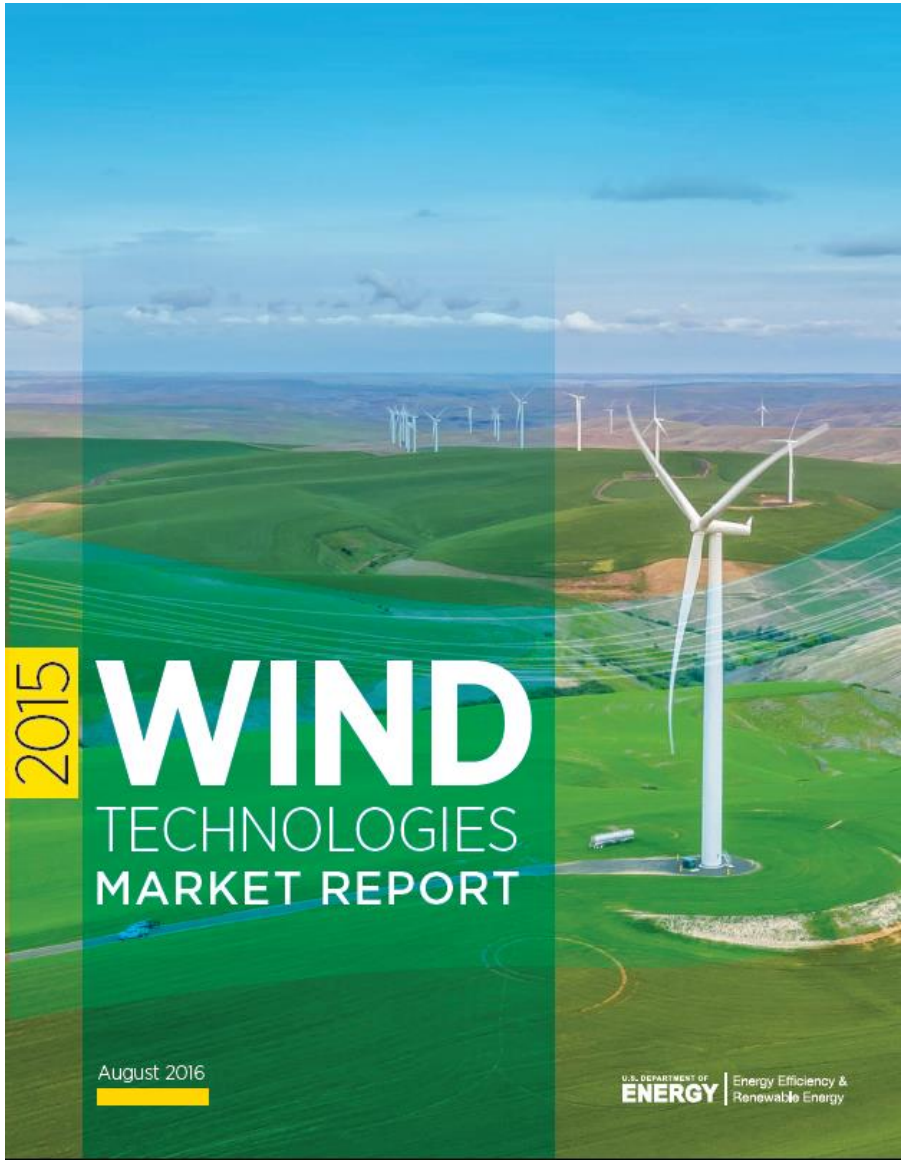
Funded by: U.S. DOE Wind Energy Technologies Office

Available at: http://energy.gov/eere/wind

Report Contents

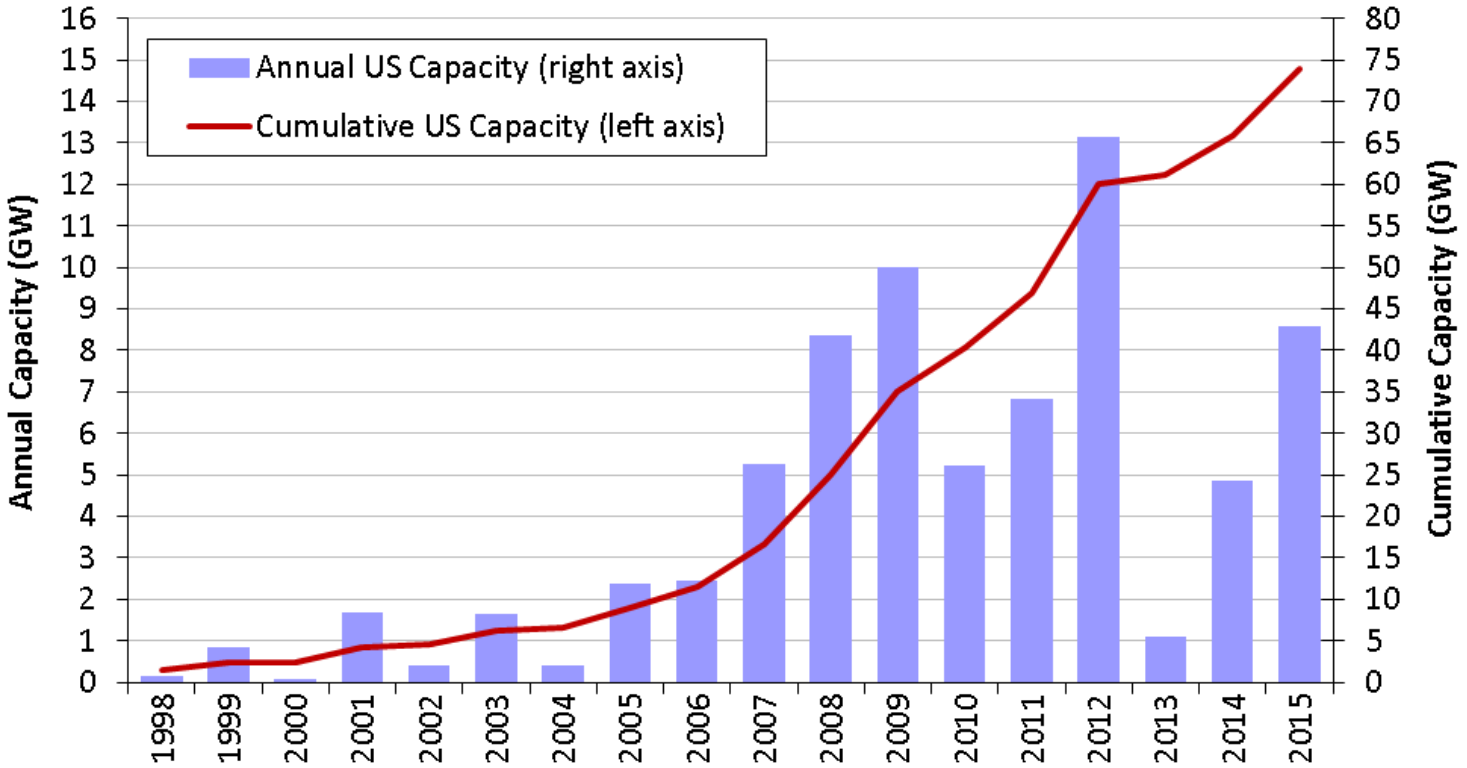
- Installation trends
- Industry trends
- Technology trends
- Performance trends
- Cost trends
- Wind power price trends
- Policy & market drivers
- Future outlook

Current presentation focuses on subset of this content



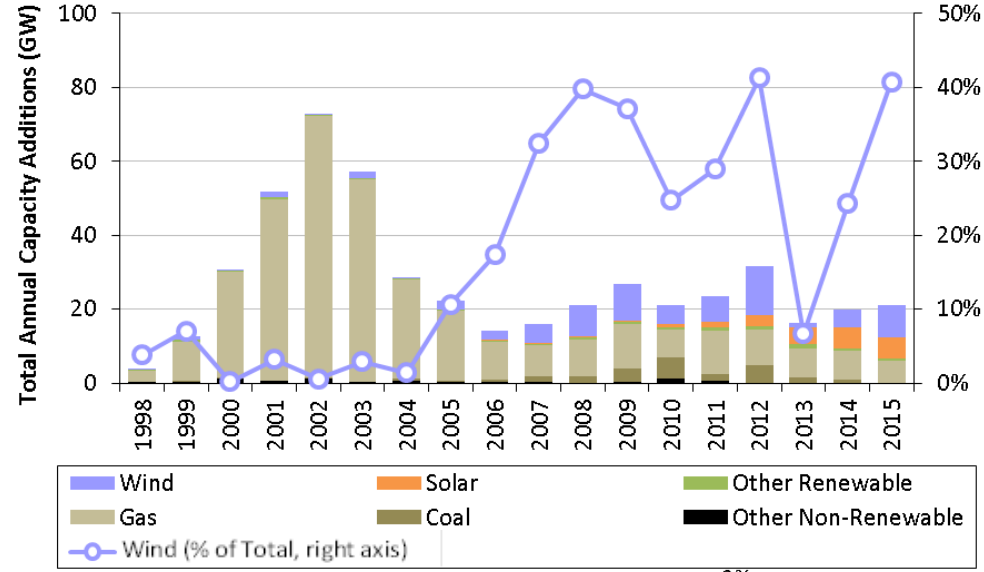
Installation Trends: A Quick Summary

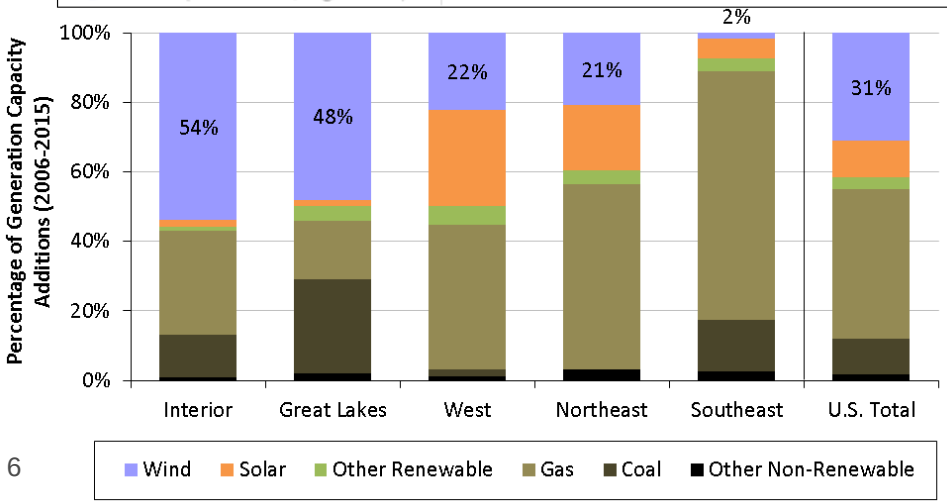
Wind Power Additions Surged in 2015, with 8,598 MW of New Capacity Added

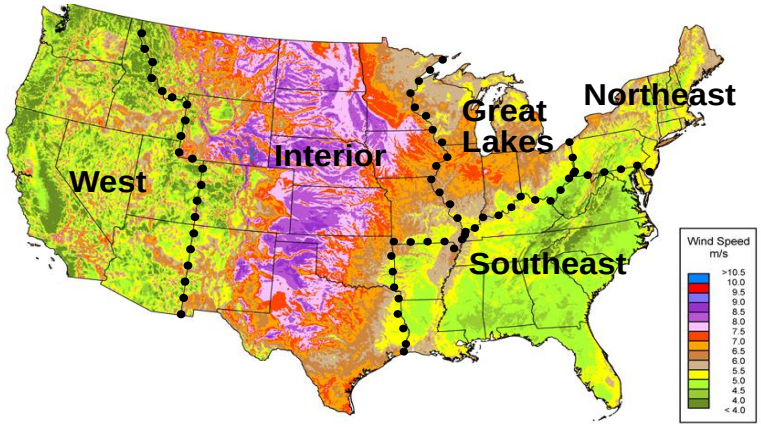


- $14.5 billion invested in wind power project additions in 2015
- More than $150 billion invested since beginning of the 1980s
- Cumulative wind capacity up 12%, bringing total to 74 GW

Wind Power Represented 41% of Electric-Generating Capacity Additions in 2015







Over last decade, wind has comprised 31% of capacity additions nation-wide, and a much higher proportion in some regions

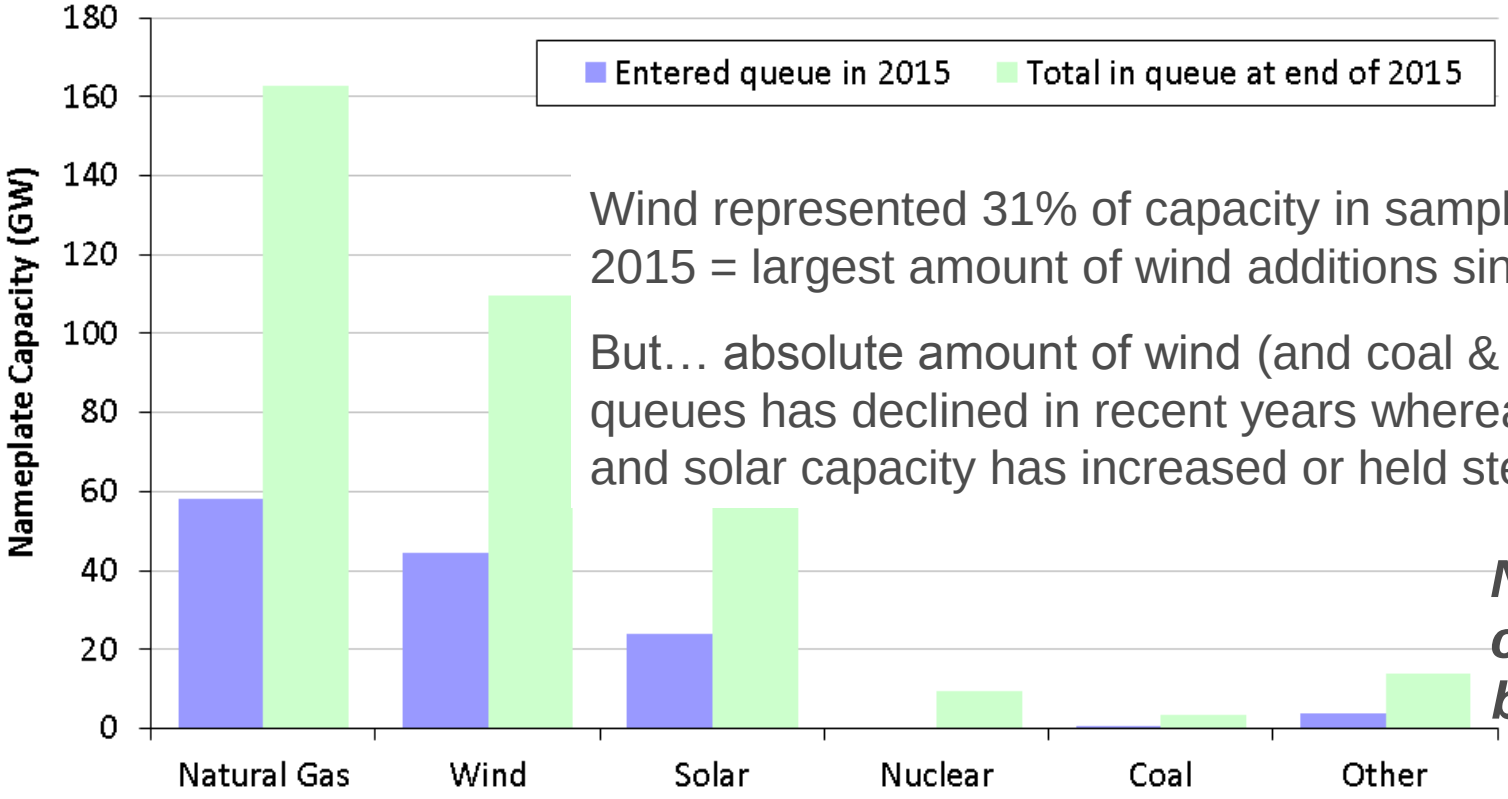
Texas Installed the Most Wind Capacity in 2015; 12 States ≥ 10% Wind Energy

Installed Capacity (MW)				Percentage of In-State Generation	
Annual (2015)		Cumulative (end of 2015)		Actual (2015)*	
Texas	3,615	Texas	17,711	Iowa	31.3%
Oklahoma	1,402	Iowa	6,209	South Dakota	25.5%
Kansas	799	California	5,662	Kansas	23.9%
Iowa	524	Oklahoma	5,184	Oklahoma	18.4%
Colorado	399	Illinois	3,842	North Dakota	17.7%
Illinois	274	Kansas	3,764	Minnesota	17.0%
New Mexico	268	Minnesota	3,235	Idaho	16.2%
North Dakota	258	Oregon	3,153	Vermont	15.4%
Minnesota	200	Washington	3,075	Colorado	14.2%
California	194	Colorado	2,965	Oregon	11.3%
South Dakota	175	North Dakota	2,143	Maine	10.5%
Maine	173	Indiana	1,895	Texas	10.0%
Indiana	150	New York	1,749	Nebraska	8.0%
Nebraska	80	Michigan	1,531	Wyoming	7.7%
Arizona	30	Wyoming	1,410	Montana	6.6%
Maryland	30	Pennsylvania	1,340	Washington	6.5%
New Hampshire	14	New Mexico	1,080	New Mexico	6.3%
Ohio	8	South Dakota	977	California	6.2%
Connecticut	5	Idaho	973	Hawaii	6.1%
New York	1	Nebraska	890	Illinois	5.5%
Rest of U.S.	0	*Rest of U.S.*	5,203	*Rest of U.S.*	1.0%
TOTAL	**8,598**	**TOTAL**	**73,992**	**TOTAL**	**4.7%**

* Based on 2015 wind and total generation by state from EIA's *Electric Power Monthly*.

- Texas had almost 3 times as much wind capacity as the next-highest state
- 24 states had > 500 MW of capacity at end of 2015 (17 > 1 GW, 11 > 2 GW)
- IA = 31% of total in-state generation from wind; SD = 26%, KS = 24%; 12 states ≥ 10%)

Interconnection Queues Demonstrate that a Substantial Amount of Wind Is Under Consideration



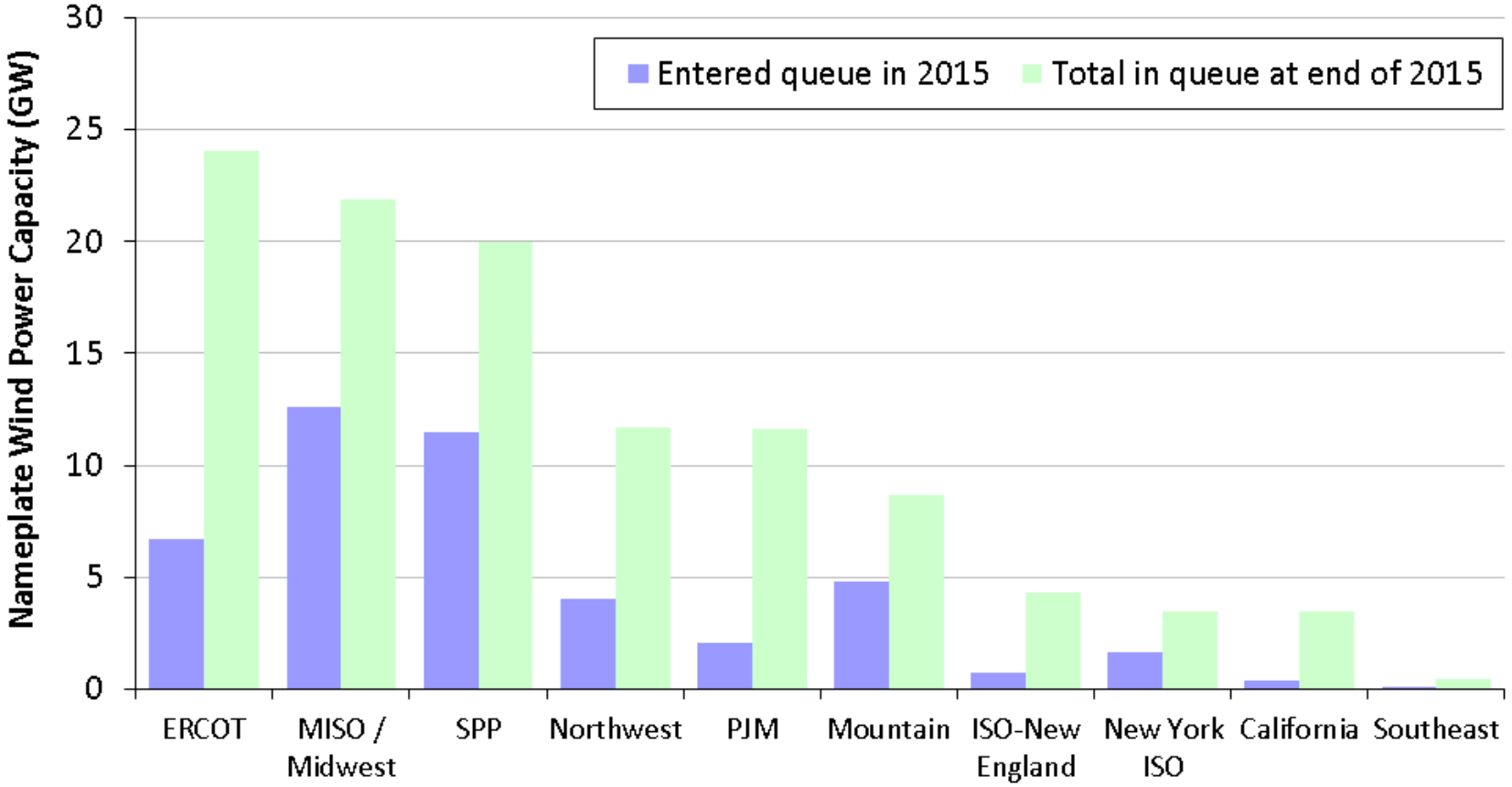
Wind represented 31% of capacity in sampled 34 queues; 2015 = largest amount of wind additions since 2010

But… absolute amount of wind (and coal & nuclear) in queues has declined in recent years whereas natural gas and solar capacity has increased or held steady

Not all of this capacity will be built….

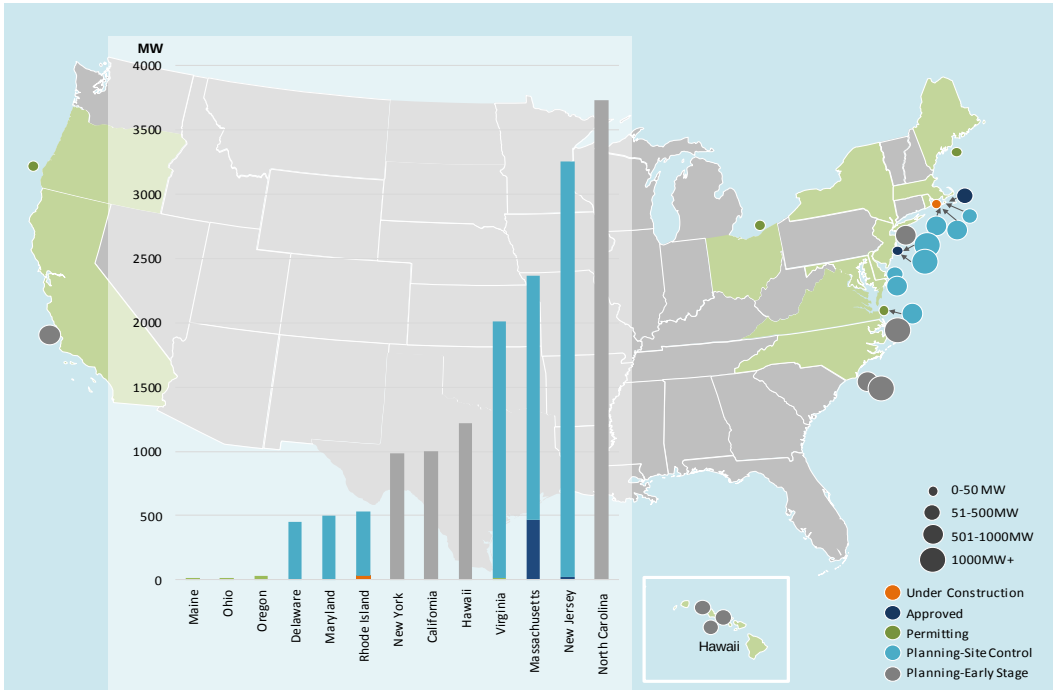
- AWEA reports 15 GW of capacity under construction after 1Q2016

Larger Amounts of Wind Planned for Texas, Midwest, Southwest Power Pool, Northwest, PJM, and Mountain Region



Not all of this capacity will be built….

First Commercial Offshore Turbines To Be Commissioned in 2016 Amid Mixed Market Signals

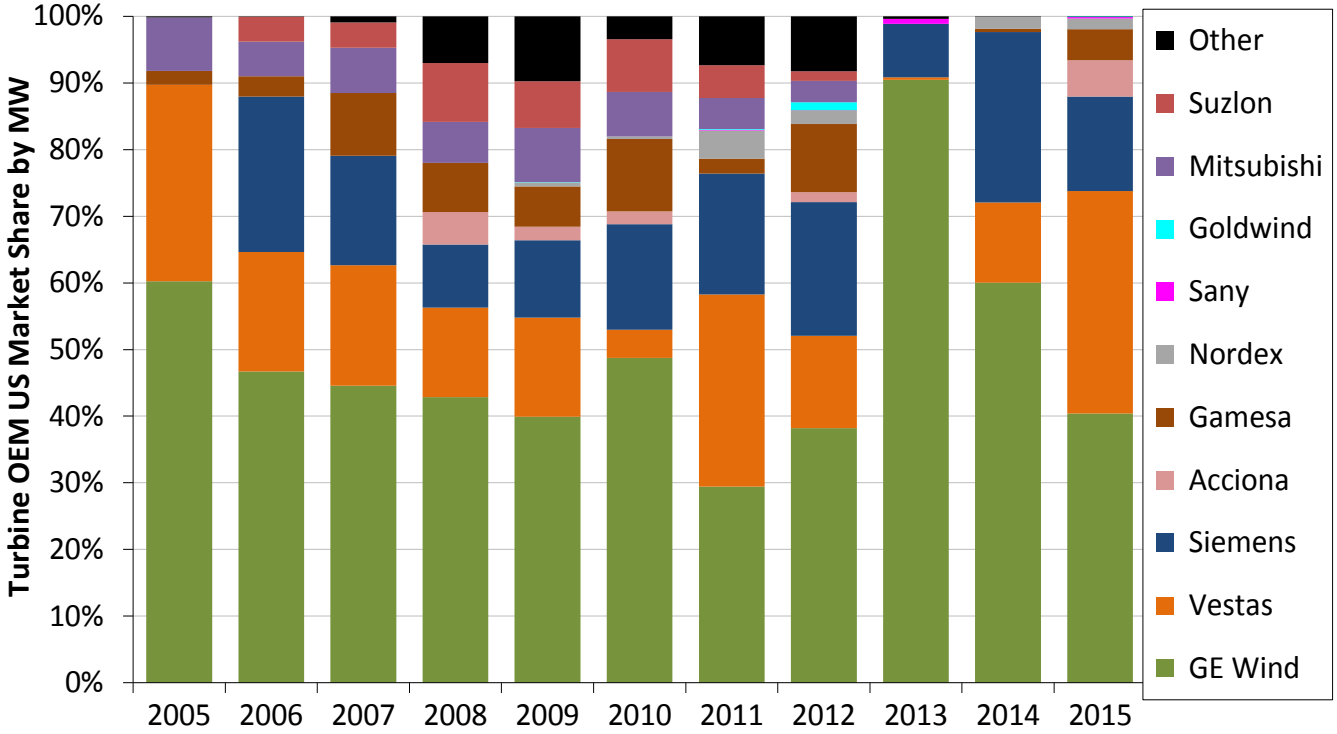


23 proposed offshore projects in various stages of development, totaling > 16 GW of potential capacity

- 30 MW Block Island project (RI) to be commissioned in 2016
- BOEM has granted multiple leases as of end of 2015; DOE funding 3 pilot deployments (NJ, ME, OH)
- Legal and political headwind for high-profile projects:
  - Cape Wind (MA) power purchase agreements cancelled by utilities
  - Fishermen's Atlantic City (NJ) rejected twice by state PUC
  - Dominion (VA) announced delay; DOE withdrew funding offer
- Pressing challenges include cost, lack of PPAs and policy incentives, regulatory complexity

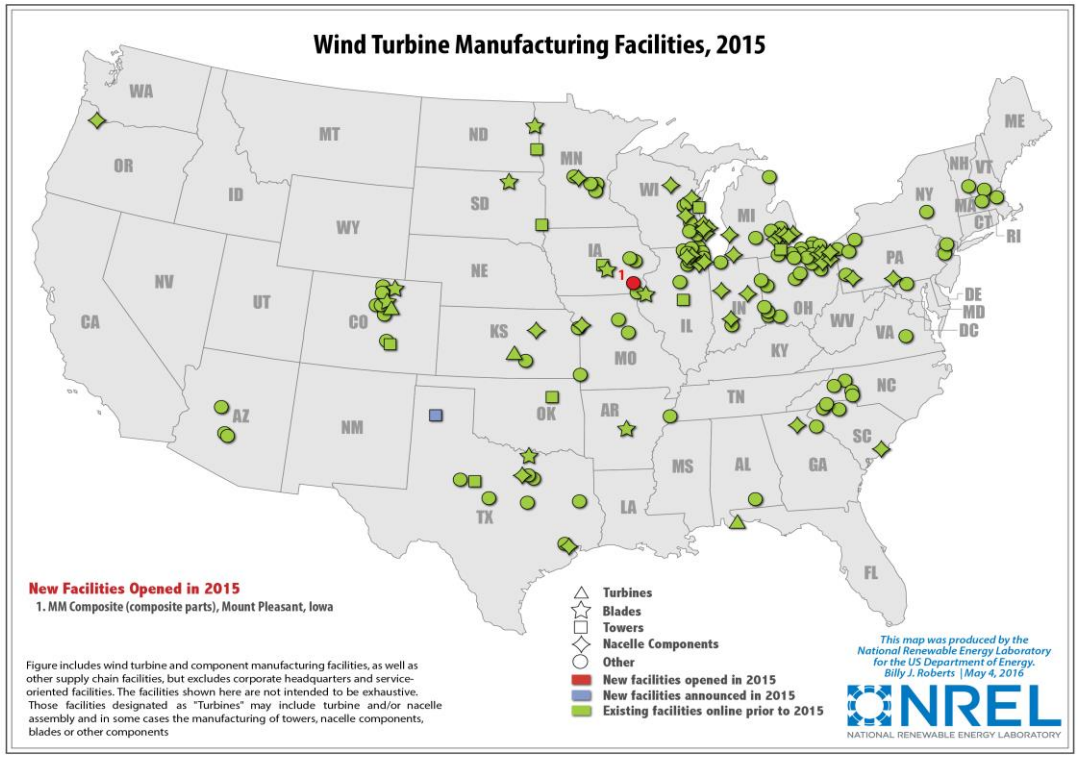
Industry Trends

GE and Vestas Captured 73% of the U.S. Market in 2014



- Recent dominance of the three-largest turbine suppliers in the U.S. market
- Globally, Goldwind and Vestas were the top suppliers, followed by GE
- Chinese suppliers occupied 5 of the top 10 spots in the global ranking, based almost entirely on sales within their domestic market

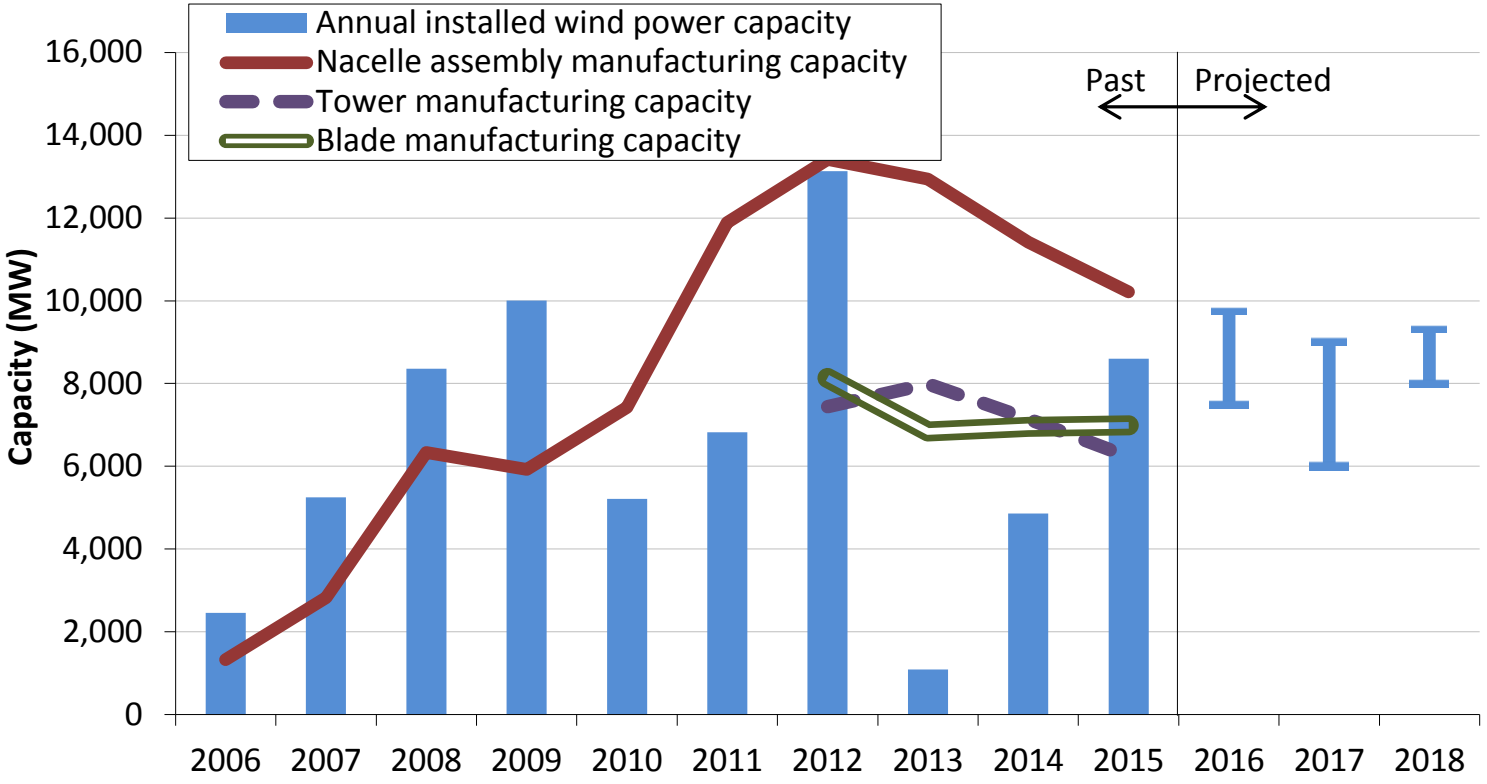
Manufacturing Supply Chain Continued to Adjust to Swings in Domestic Demand



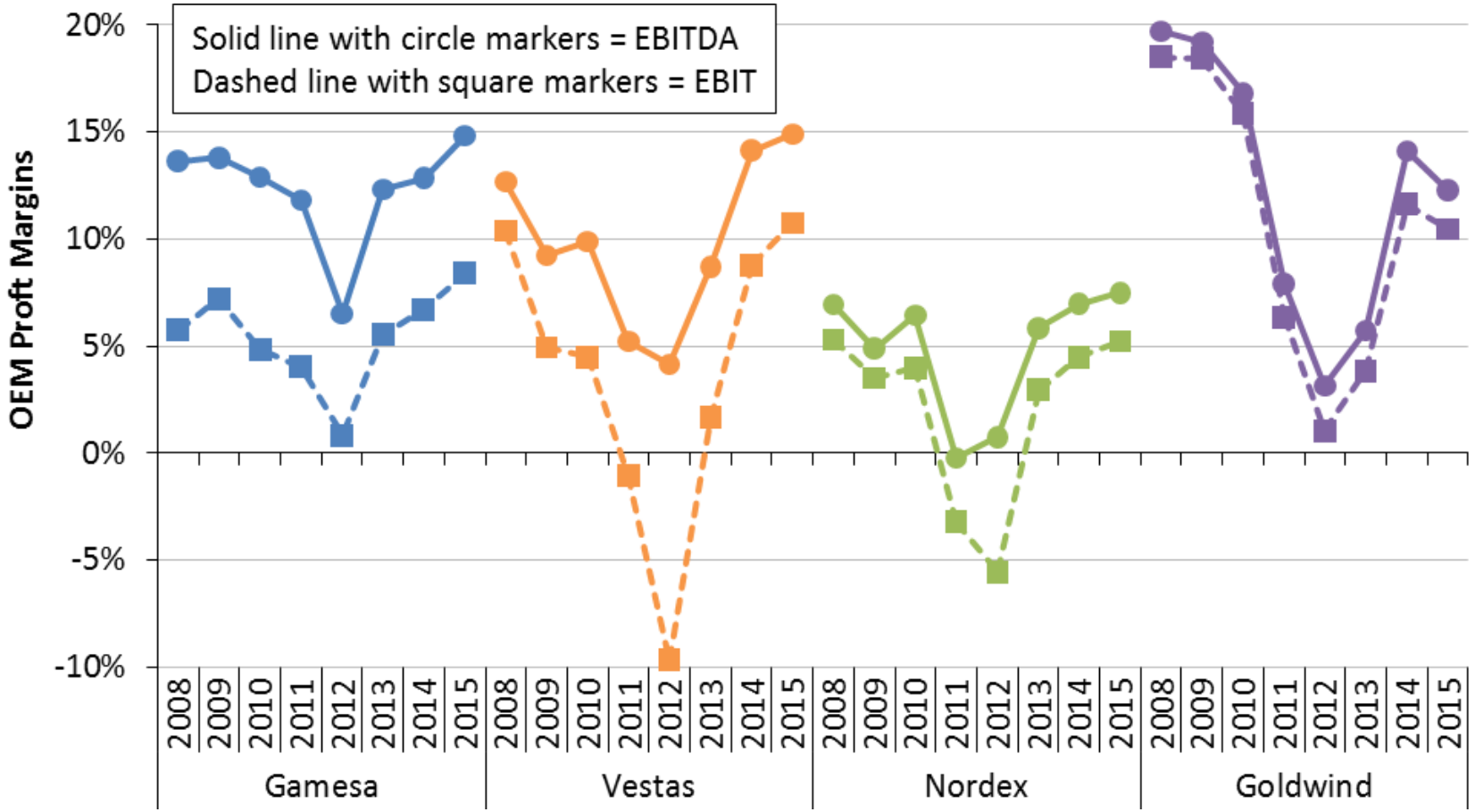
Note: map not intended to be exhaustive

- Upswing in near- to medium-term expected growth, but strong competitive pressures and possible reduced demand over time as the PTC is phased down
- 3 domestic manufacturing facility closures in 2015; 1 new opening
- Many manufacturers remain: over last decade, manufacturers have localized and expanded U.S. presence; "Big 3" OEMs all have at least one facility
- Wind related jobs increased from 73,000 in 2014 to 88,000 in 2015

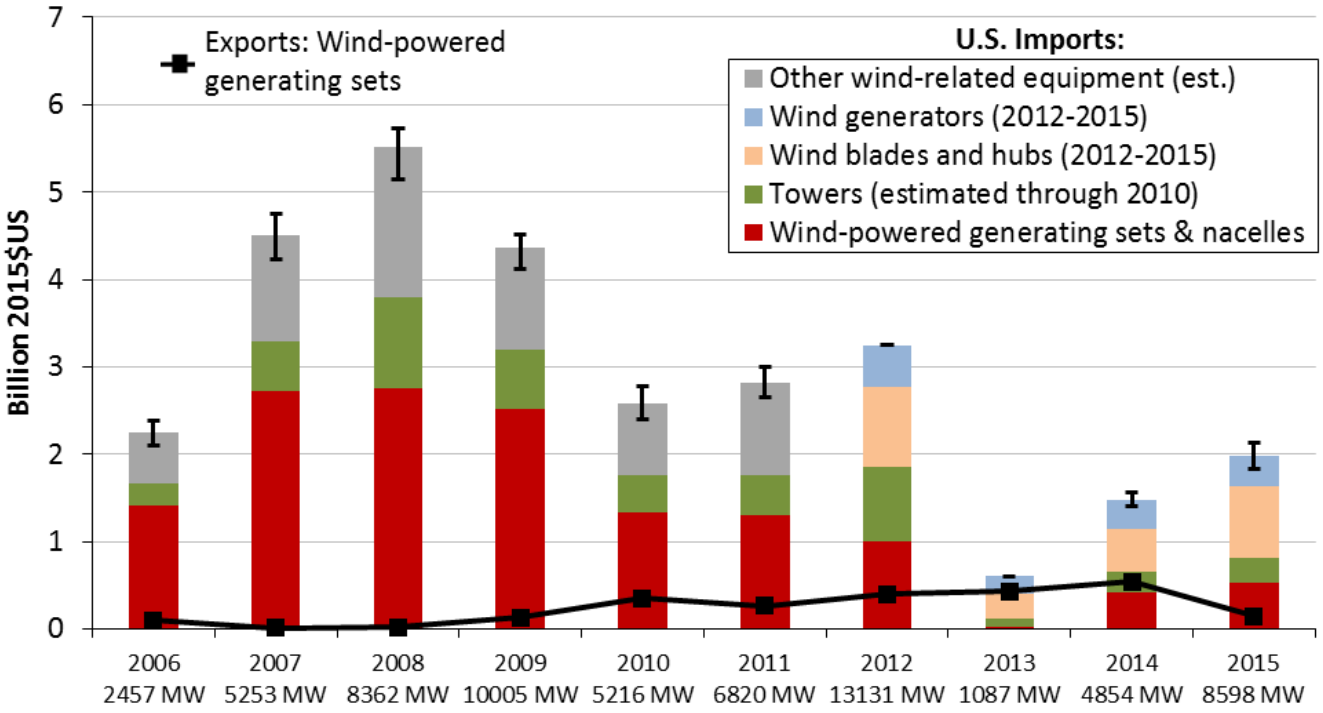
Domestic Manufacturing Capability for Nacelle Assembly, Towers, and Blades Is Reasonably Well Balanced Against Near-Term Demand Forecasts



Turbine OEM Profitability Has Generally Rebounded Over the Last Three Years



Imports of Wind Equipment Are Sizable; Exports Declined in 2015

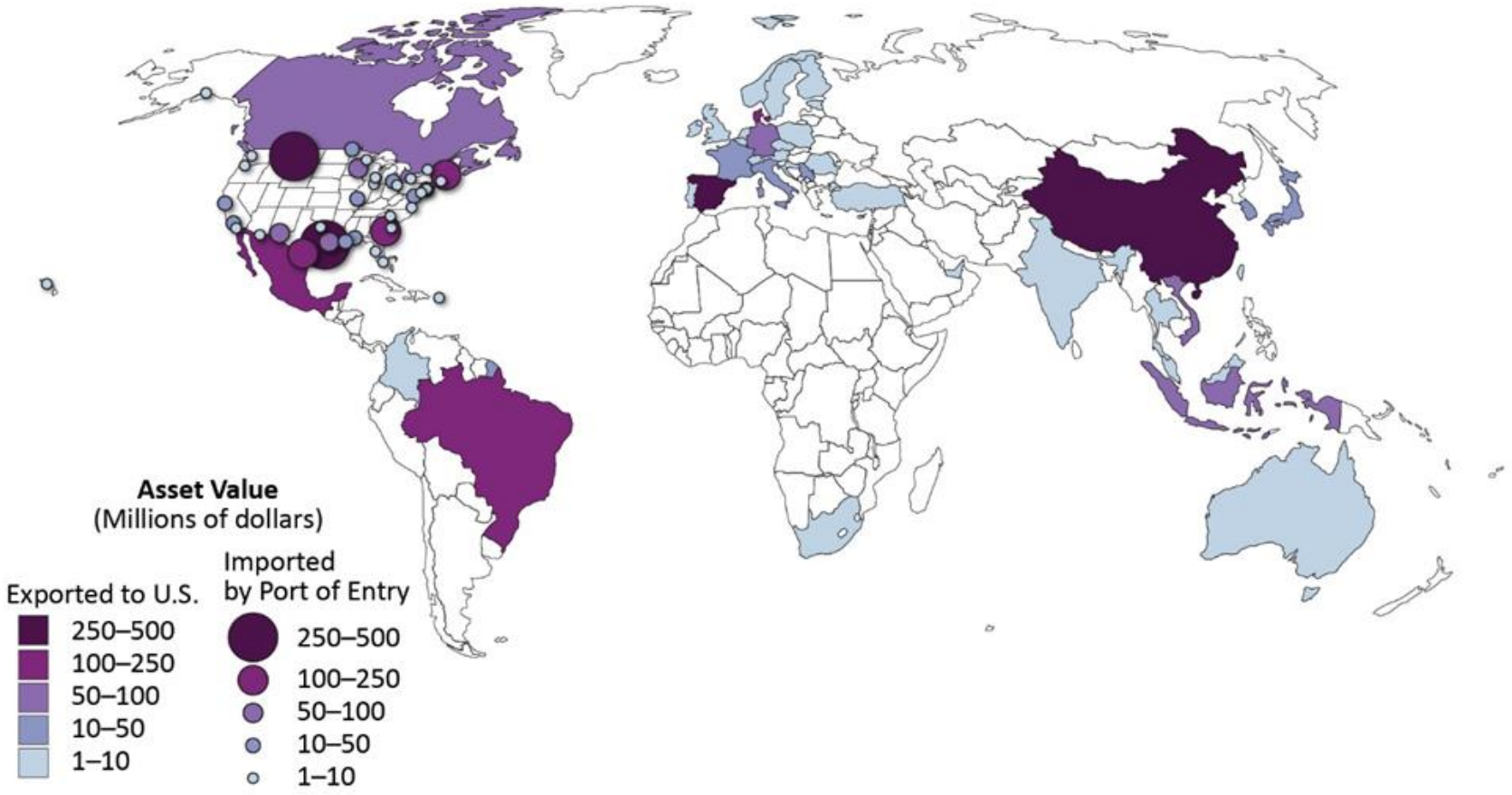


U.S. is a net importer of wind equipment

Exports of wind-powered generating sets decreased to $149 million in 2015; no ability to track other wind-specific exports, but total tower exports equalled $63 million

- *Figure only includes tracked trade categories; misses other wind-related imports*
- *See full report for the assumptions used to generate this figure*

Tracked Wind Equipment Imports in 2015: 40% Asia, 38% Europe, 22% Americas



Note: Tracked wind-specific equipment includes: wind-powered generating sets, towers, hubs and blades, wind generators and parts

Domestic Manufacturing Content Is Strong for Nacelle Assembly, Towers, and Blades, but U.S. Is Highly Reliant on Imports for Equipment Internal to the Nacelle

Domestic Content for 2015 Turbine Installations in the U.S.

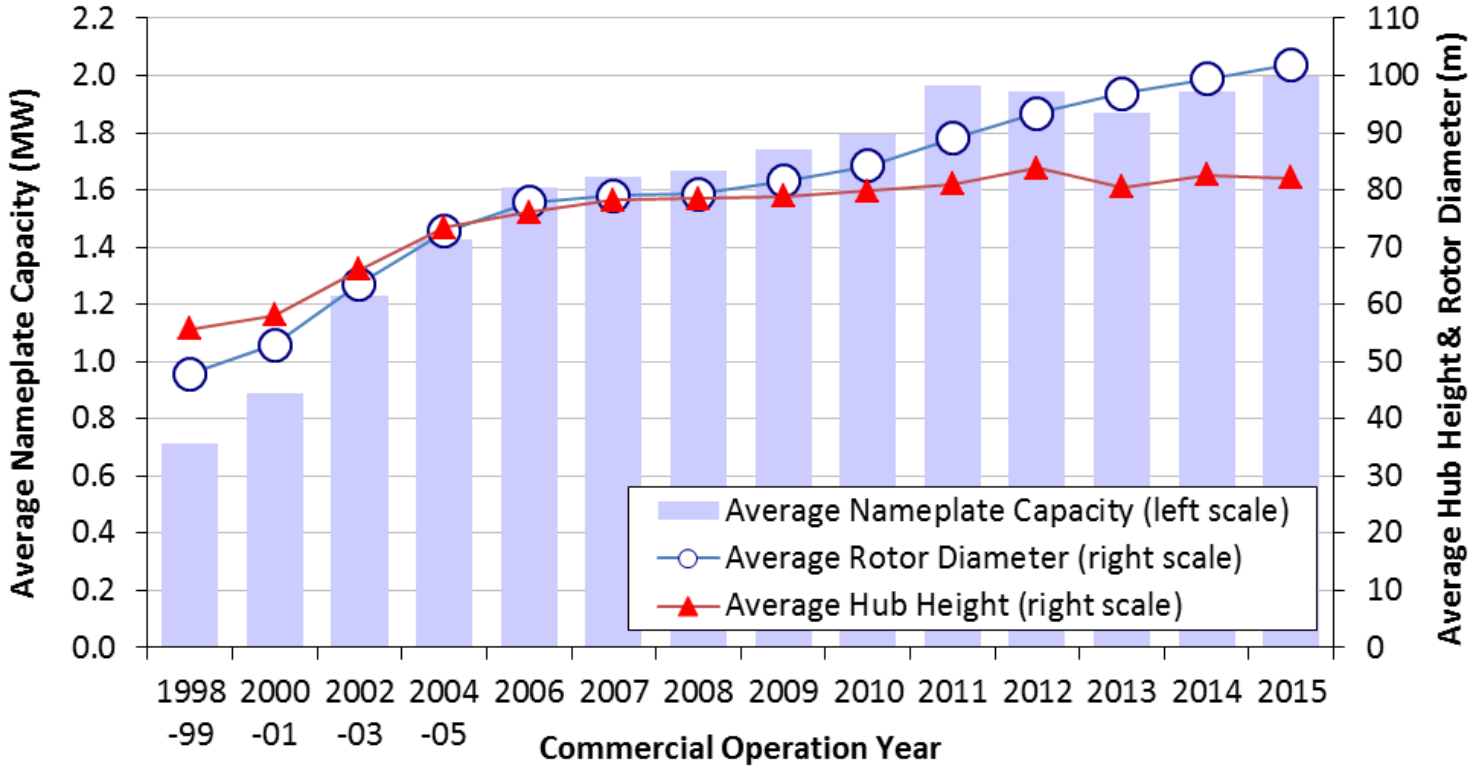
Towers	Blades & Hubs	Nacelle Assembly
80-85%	50-70%	> 85% of nacelle assembly

Imports occur in untracked trade categories, including many nacelle internals; nacelle internals generally have domestic content of < 20%

Overall estimated domestic content: ~40% in 2012 for wind turbine equipment; ~60% if considering total projects costs, including balance-of-plant

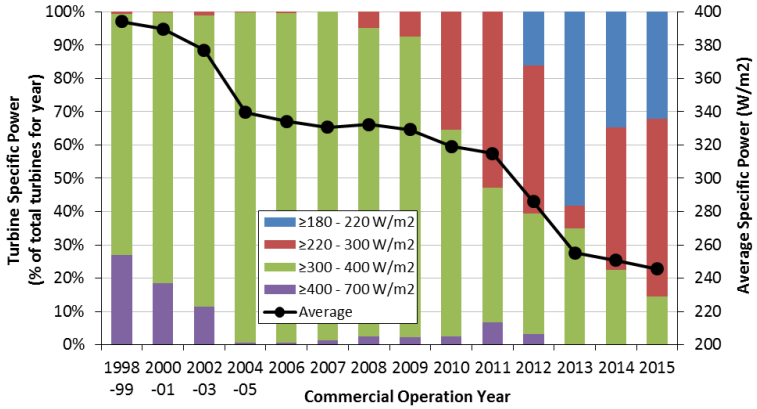
Technology Trends

Turbines Have Grown Larger Over Time; Growth in Rotor Diameter Has Outpaced Growth in Nameplate Capacity and Hub Height in Recent Years

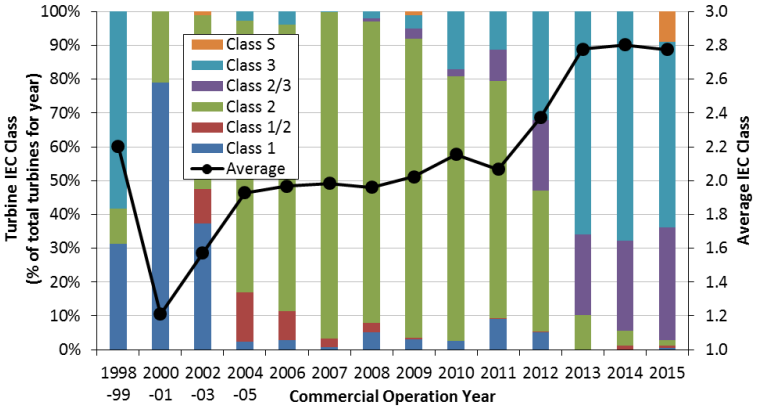


Turbines Originally Designed for Lower Wind Speed Sites Have Rapidly Gained Market Share

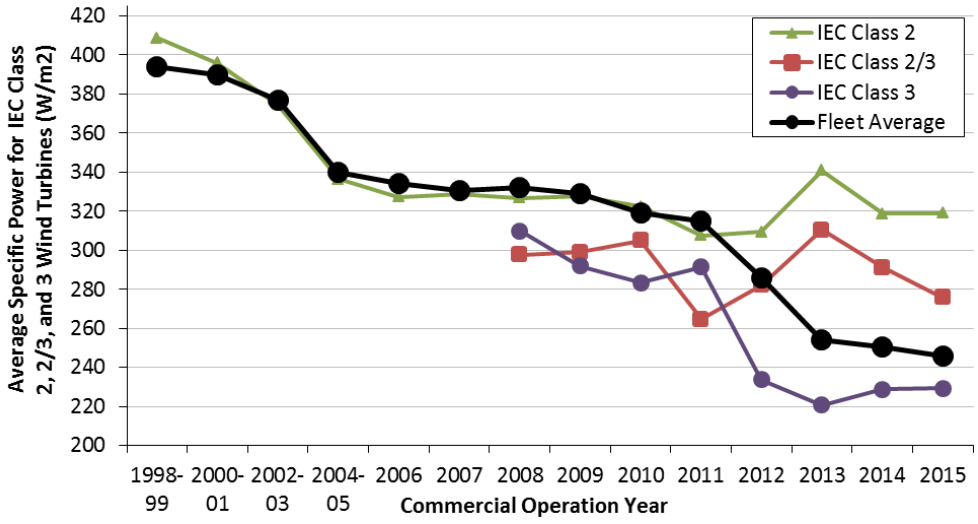
Specific Power



IEC Class



Specific Power by Selected IEC Class



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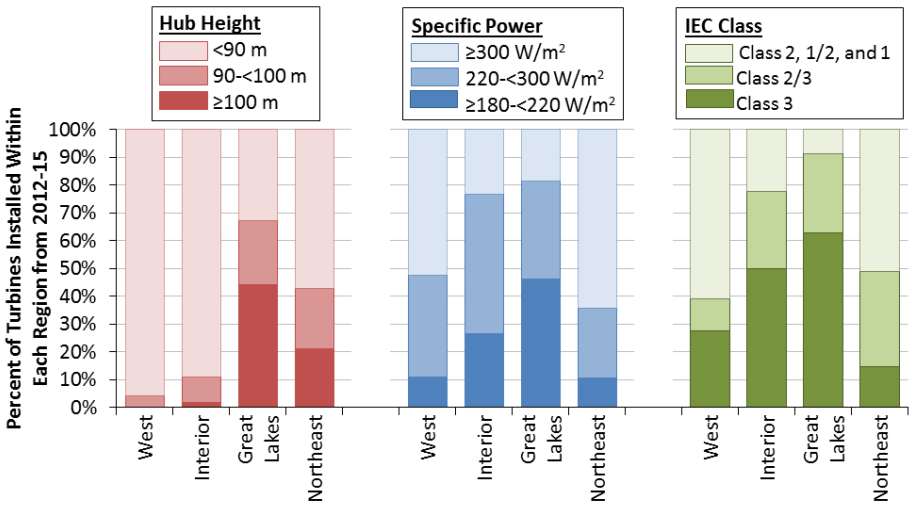
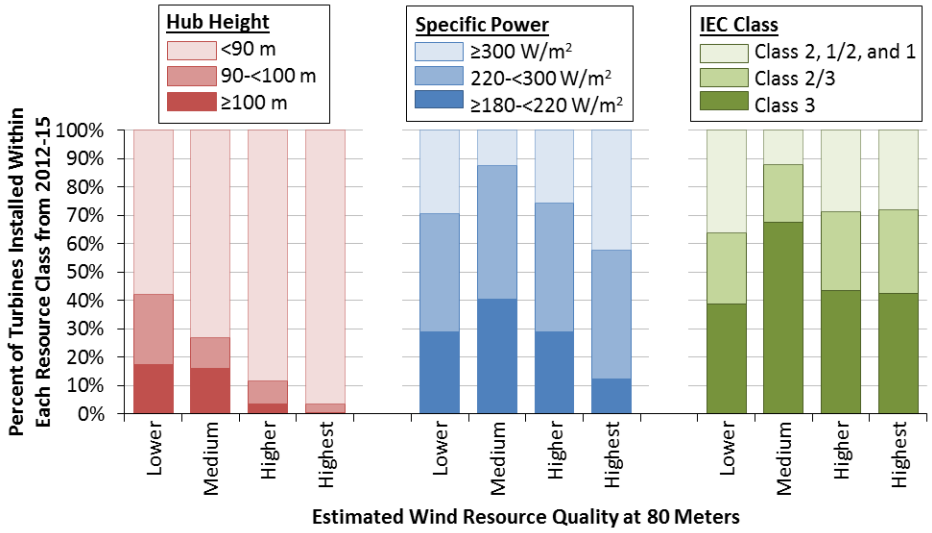
Turbines Originally Designed for Lower Wind Speeds Now Regularly Used in Lower & Higher Wind Sites; Taller Towers Predominate in Great Lakes and NE

By Region

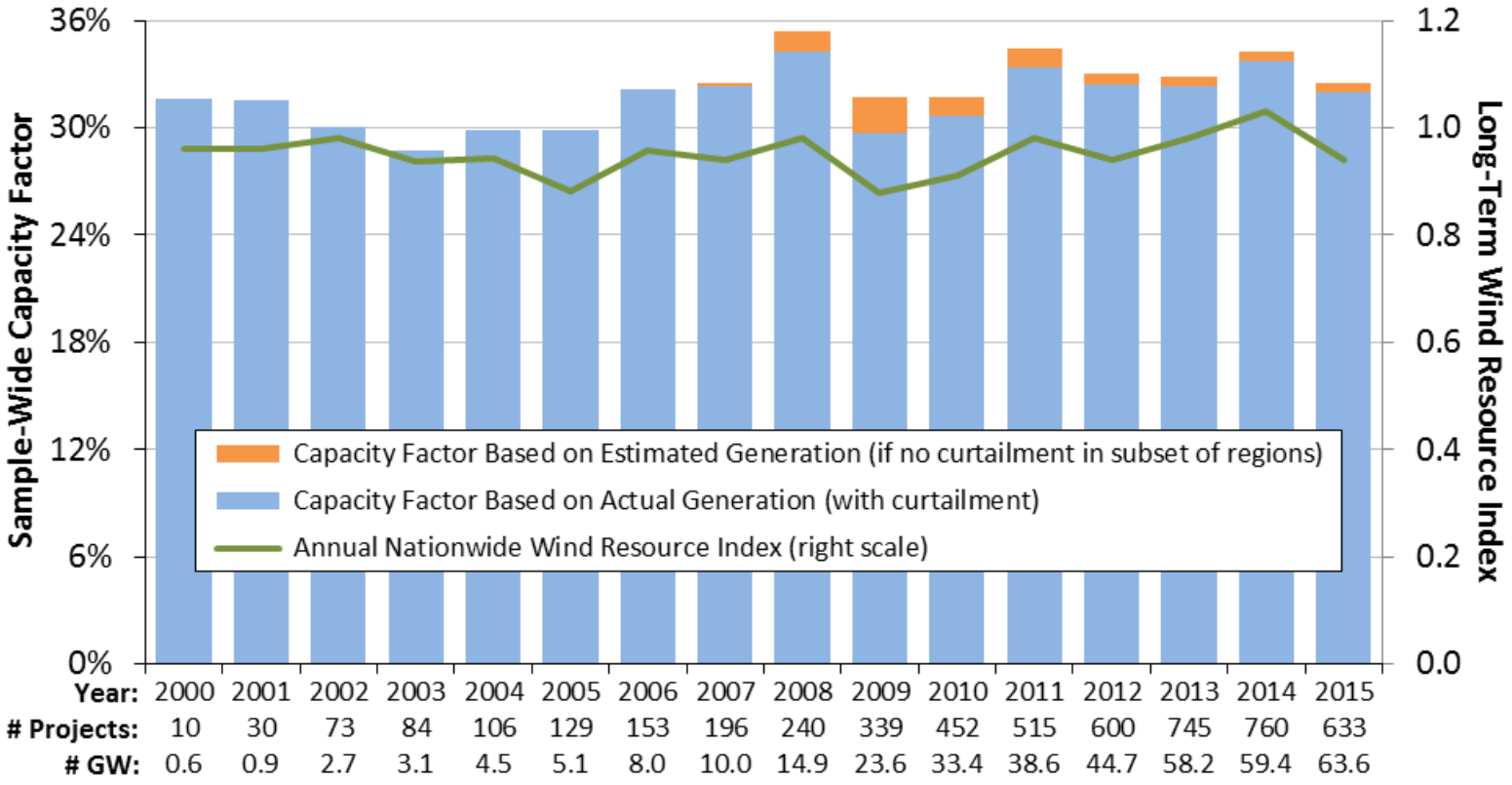


By Wind Resource Quality



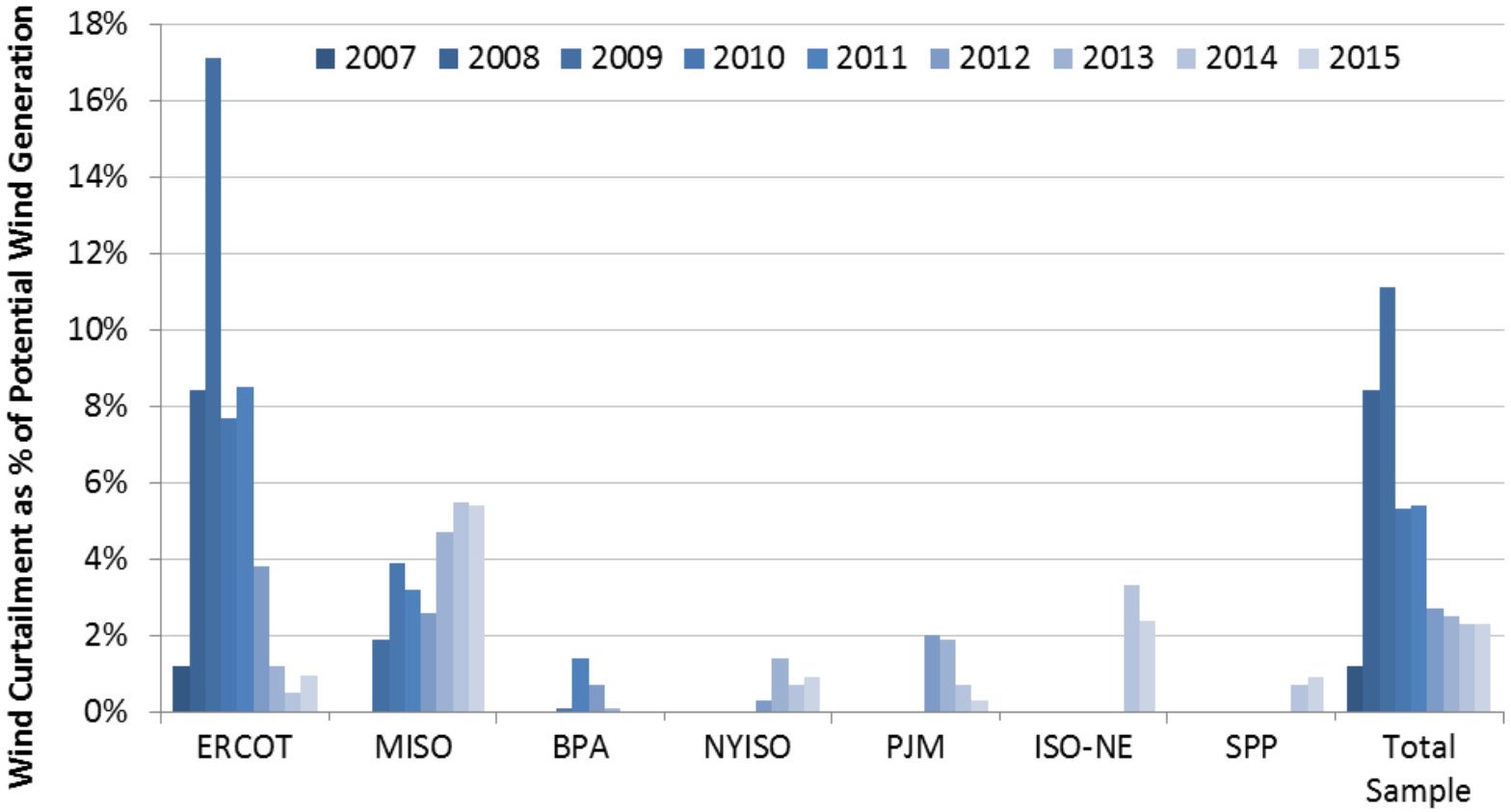
Performance Trends

Sample-Wide Capacity Factors Have Increased, but Impacted by Curtailment and Inter-Year Wind Resource Variability



Note: The wind resource index is compiled from NextEra Energy Resources reports

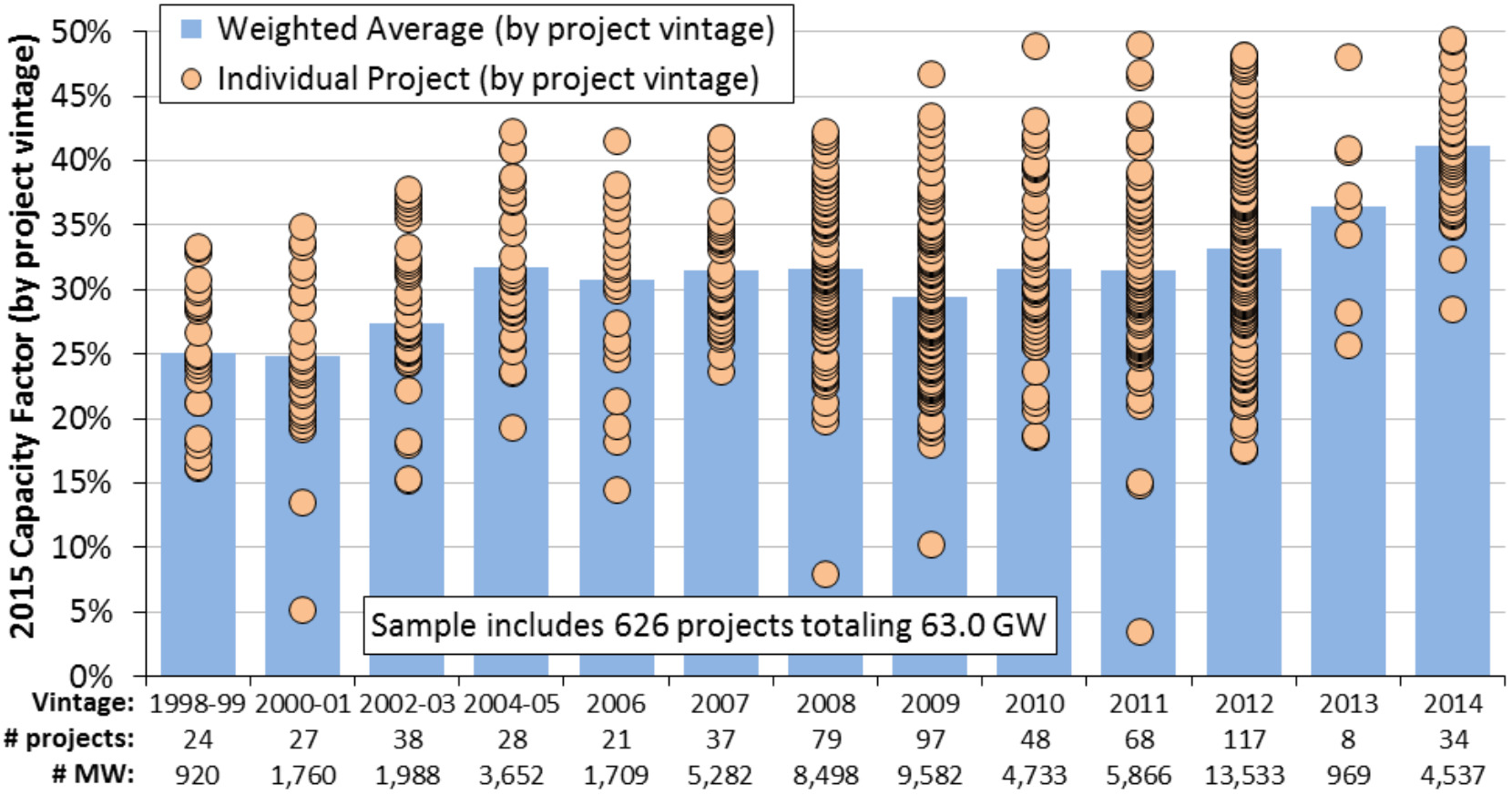
Wind Curtailment Has Generally Declined in Recent Years; Higher in MISO



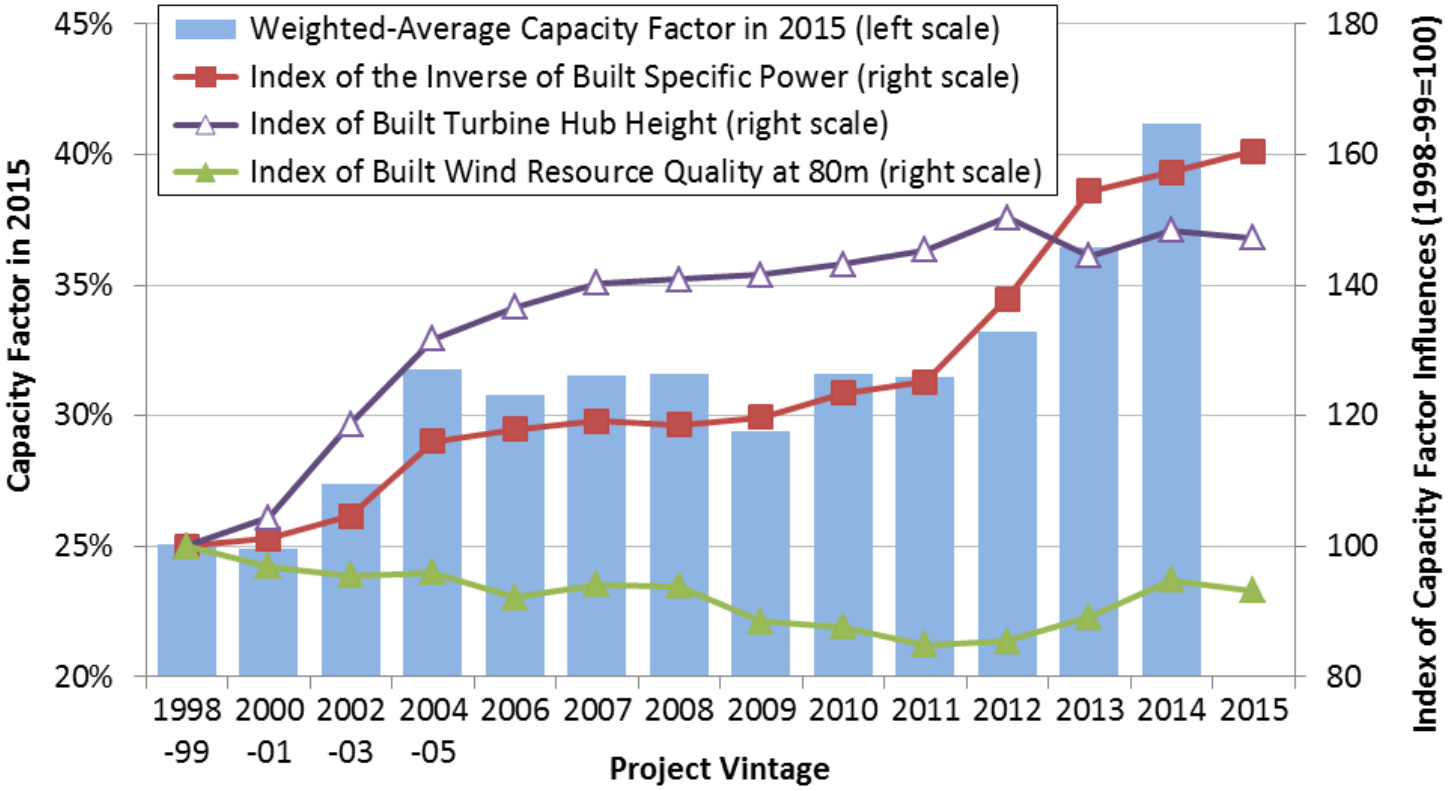
Except for BPA, data represent both forced & economic curtailment

In areas where curtailment has been particularly problematic in the past – principally in Texas – steps taken to address the issue have born fruit

Impact of Technology Trends on Capacity Factors Becomes More Apparent When Parsed by Project Vintage



Trends Explained by Competing Influence of Lower Specific Power and Higher Hub Heights vs. Build-Out of Lower Quality Wind Resource Sites through 2012



- ***Reversal*** of build-out in lower wind speed sites in 2013-2015

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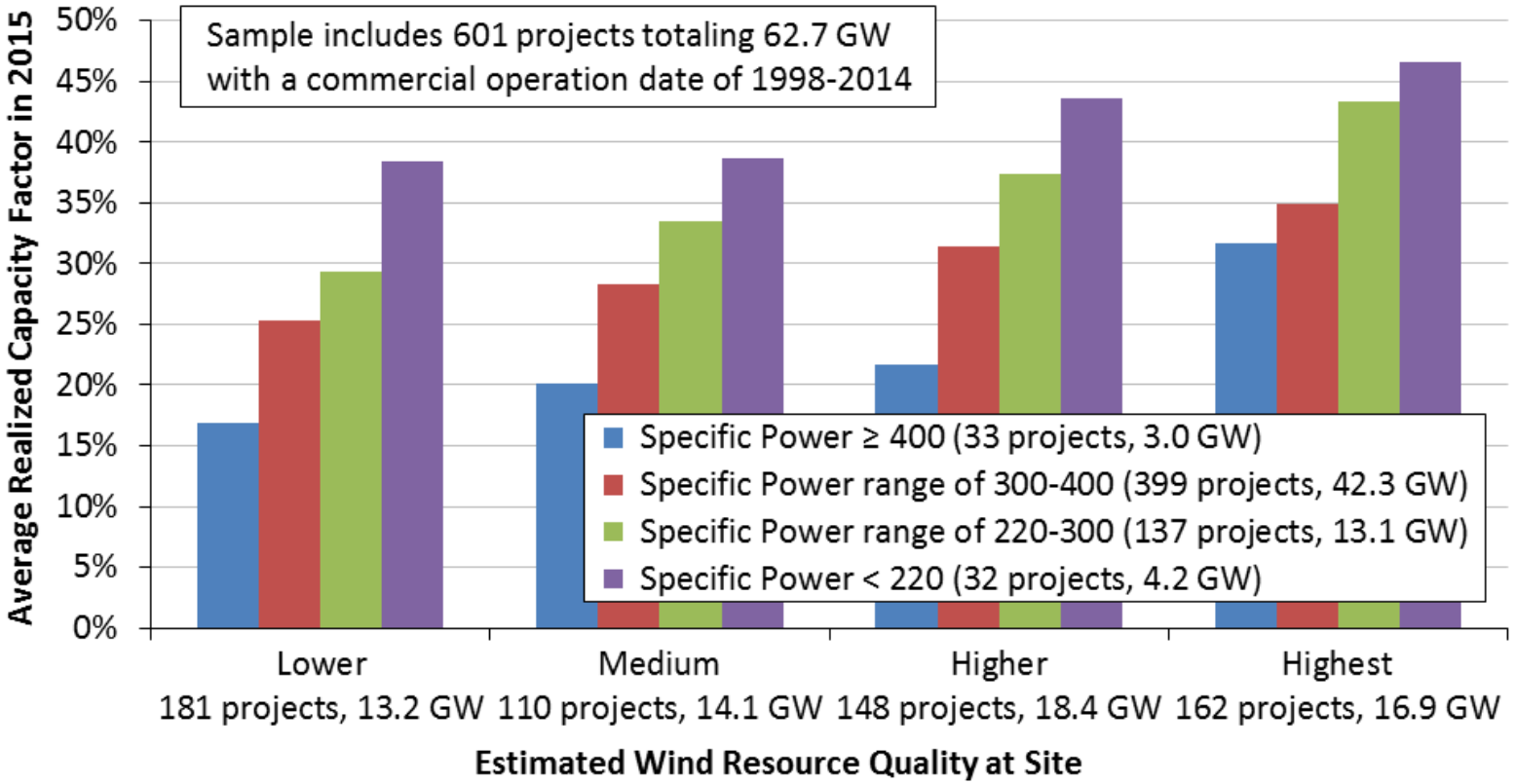
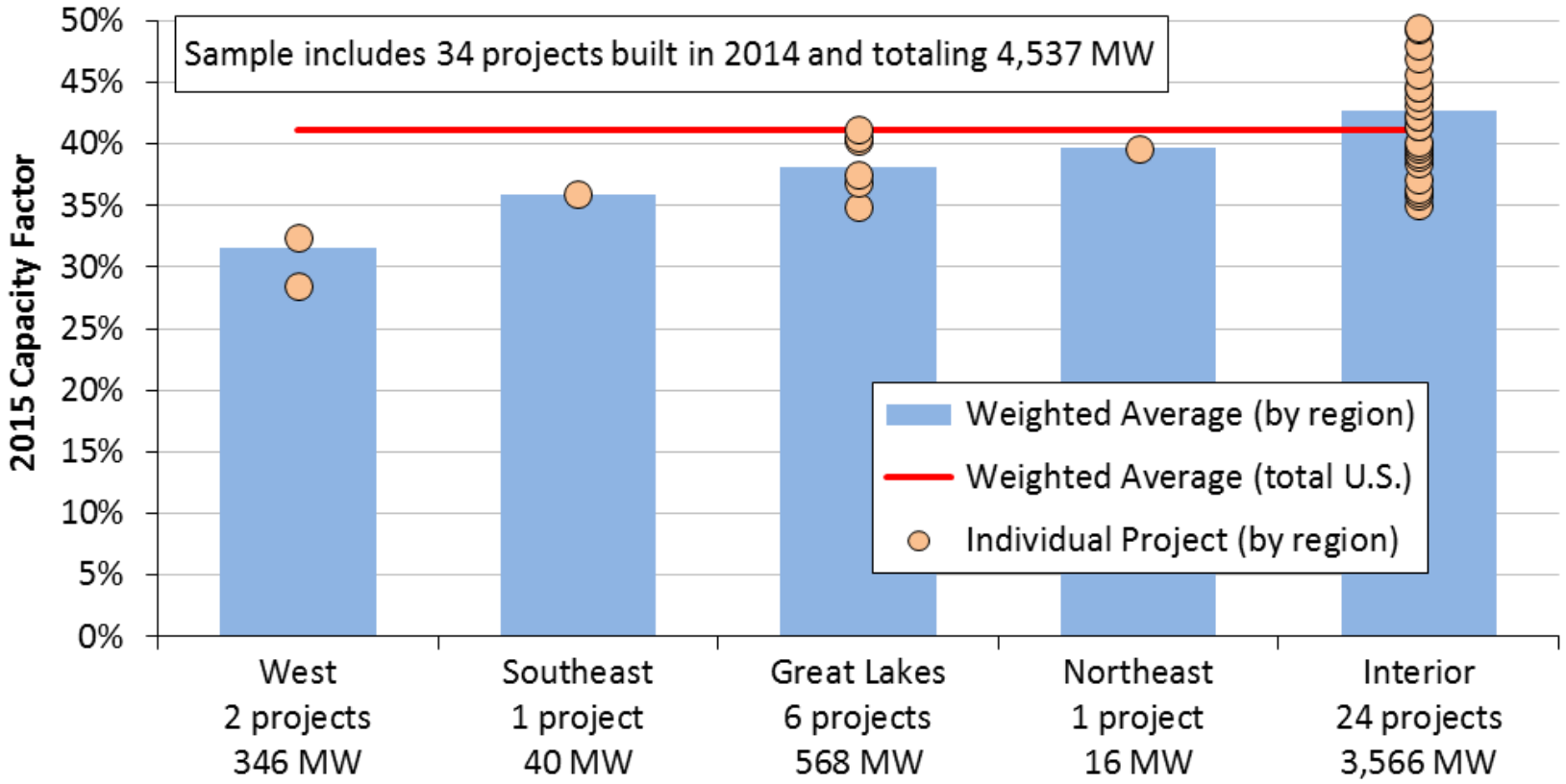
Controlling for Wind Resource Quality and Specific Power Demonstrates Impact of Turbine Evolution



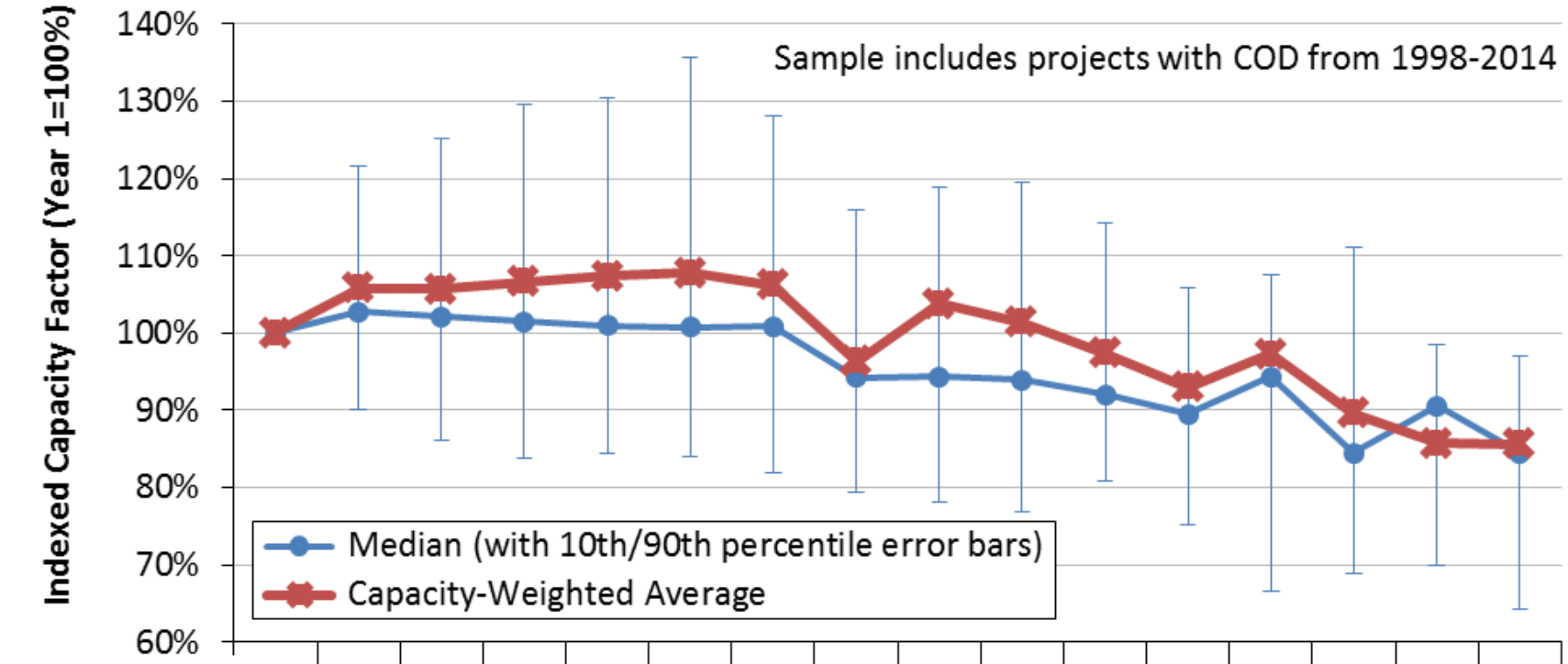
Turbine design changes are driving capacity factors higher for projects located in given wind resource regimes

Regional Variations in Capacity Factors Reflect the Strength of the Wind Resource and Adoption of New Turbine Technology



Note: Very limited sample size for 2014 projects in most regions

Degradation of Project Performance as Projects Age Also Impacts Overall Trends

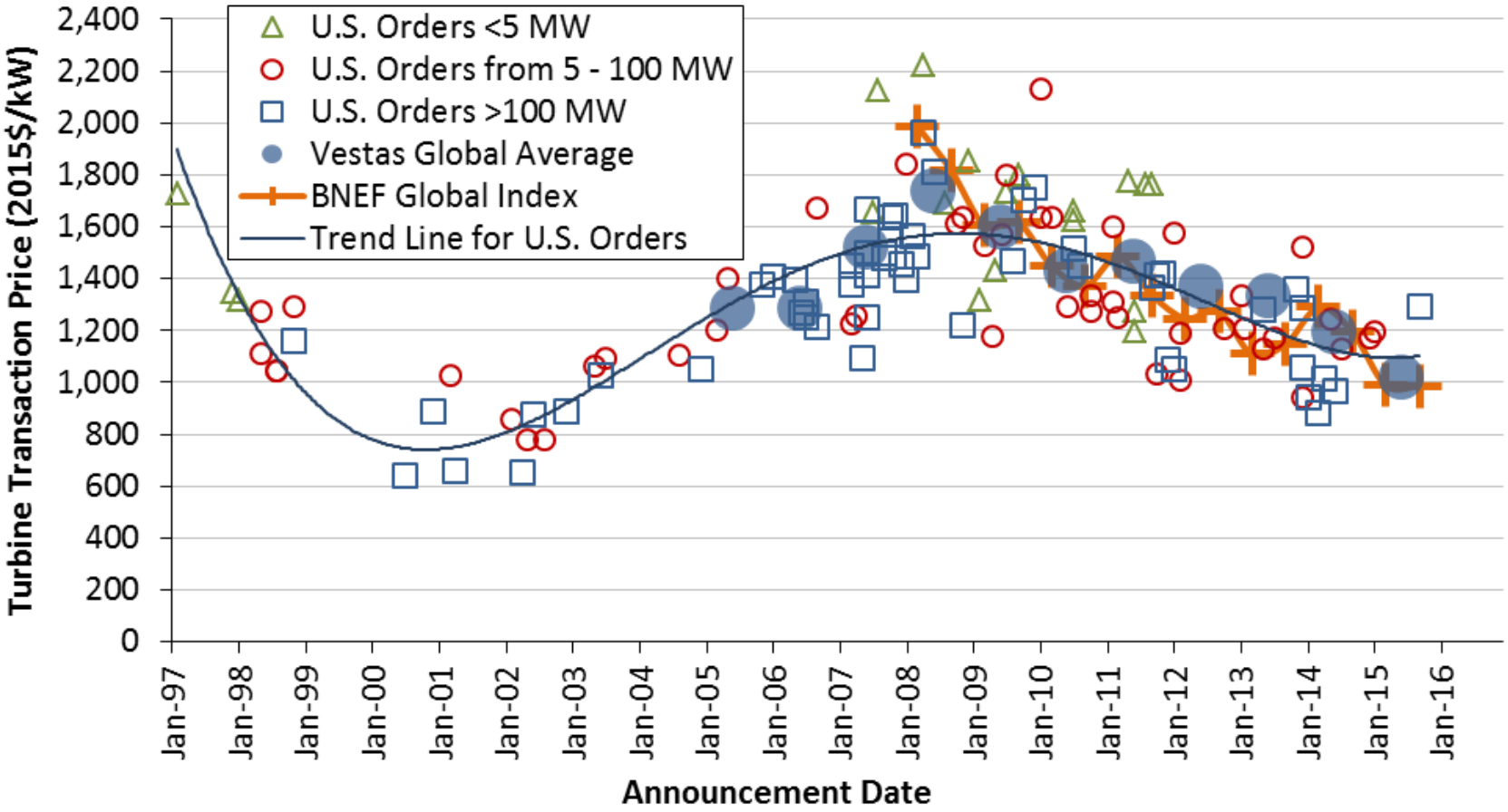


Years post-COD:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Sample GW:	63.6	58.8	57.8	44.1	38.1	33.3	23.7	15.2	9.9	8.0	5.0	4.3	2.8	2.4	0.6	0.6
Sample projects:	756	721	709	564	478	418	307	207	165	122	99	86	63	53	13	9

Note: See full report for caveats associated with this figure

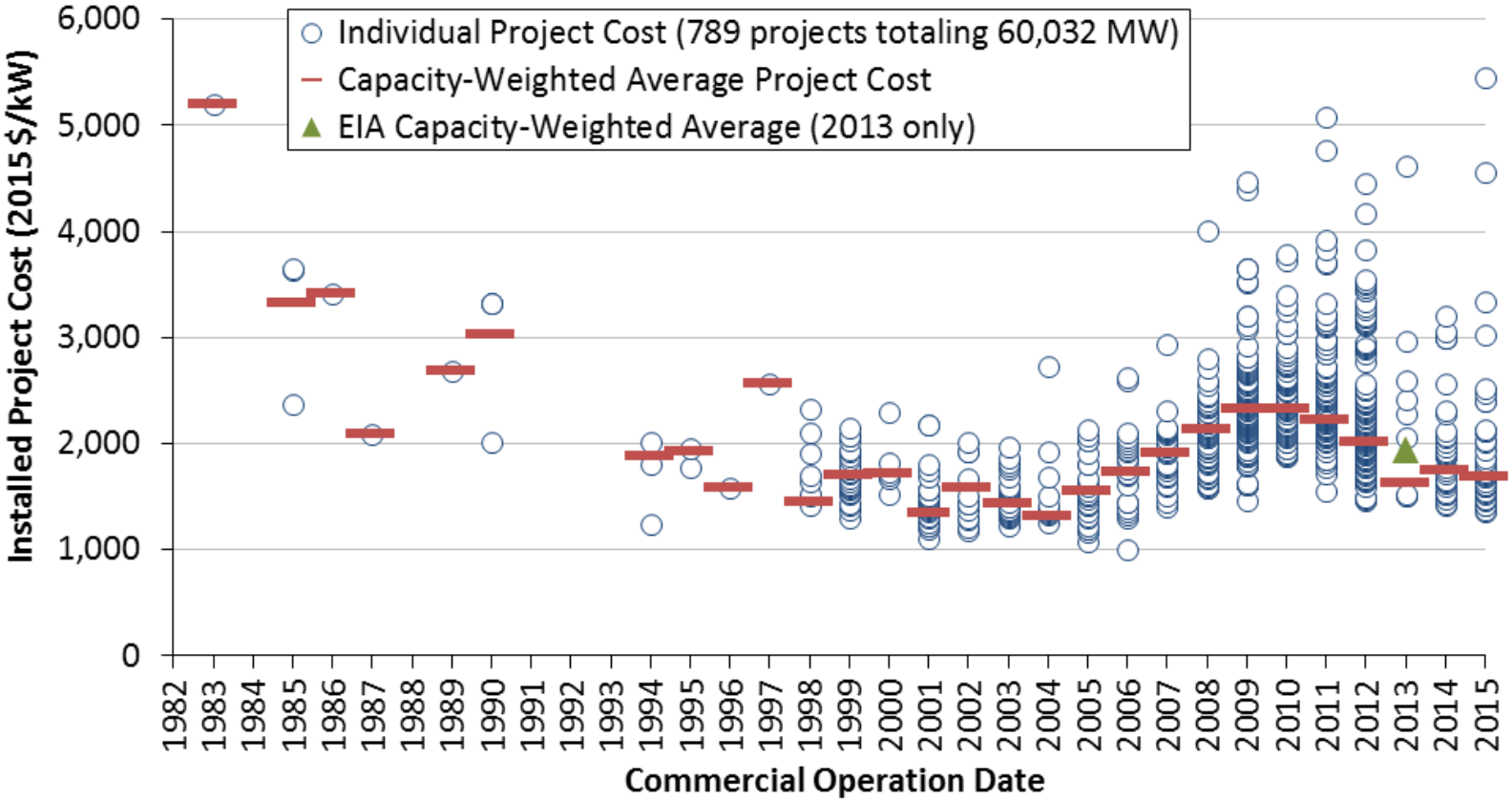
Cost Trends

Wind Turbine Prices Remained Well Below the Levels Seen Several Years Ago



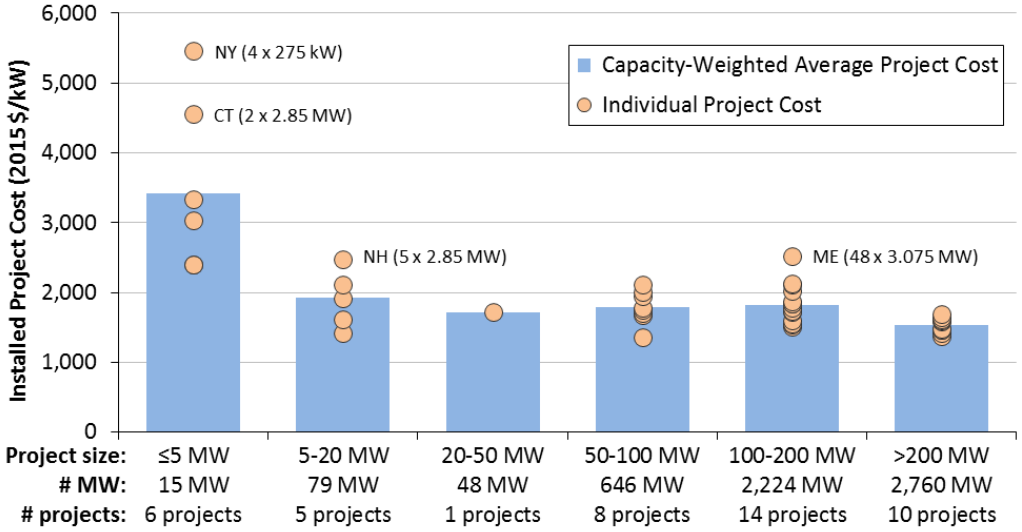
Recent turbine orders reportedly in the range of $850-1,250/kW

Lower Turbine Prices Drive Reductions in Reported Installed Project Costs

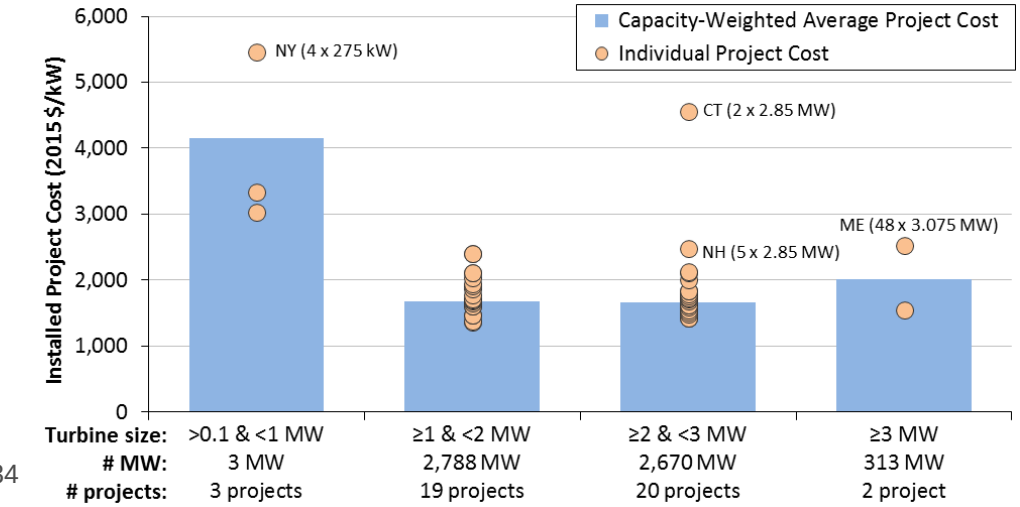


- 2015 projects had an average cost of $1,690/kW, down $640/kW since 2009 and 2010; limited sample of under-construction projects slated for completion in 2016 suggest no material change in costs

Economies of Scale, Especially at Lower End of Project & Turbine Size Range

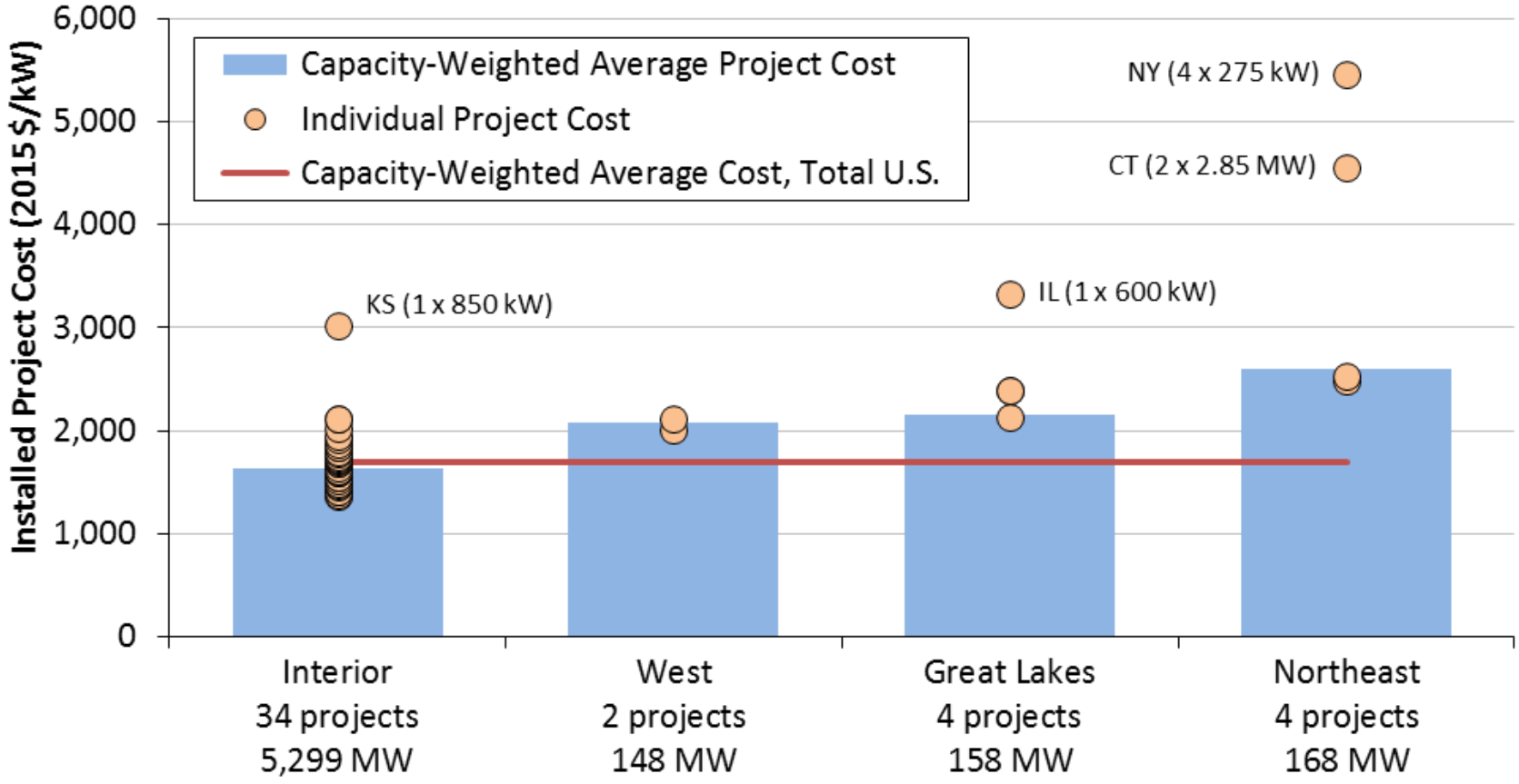


Project Size

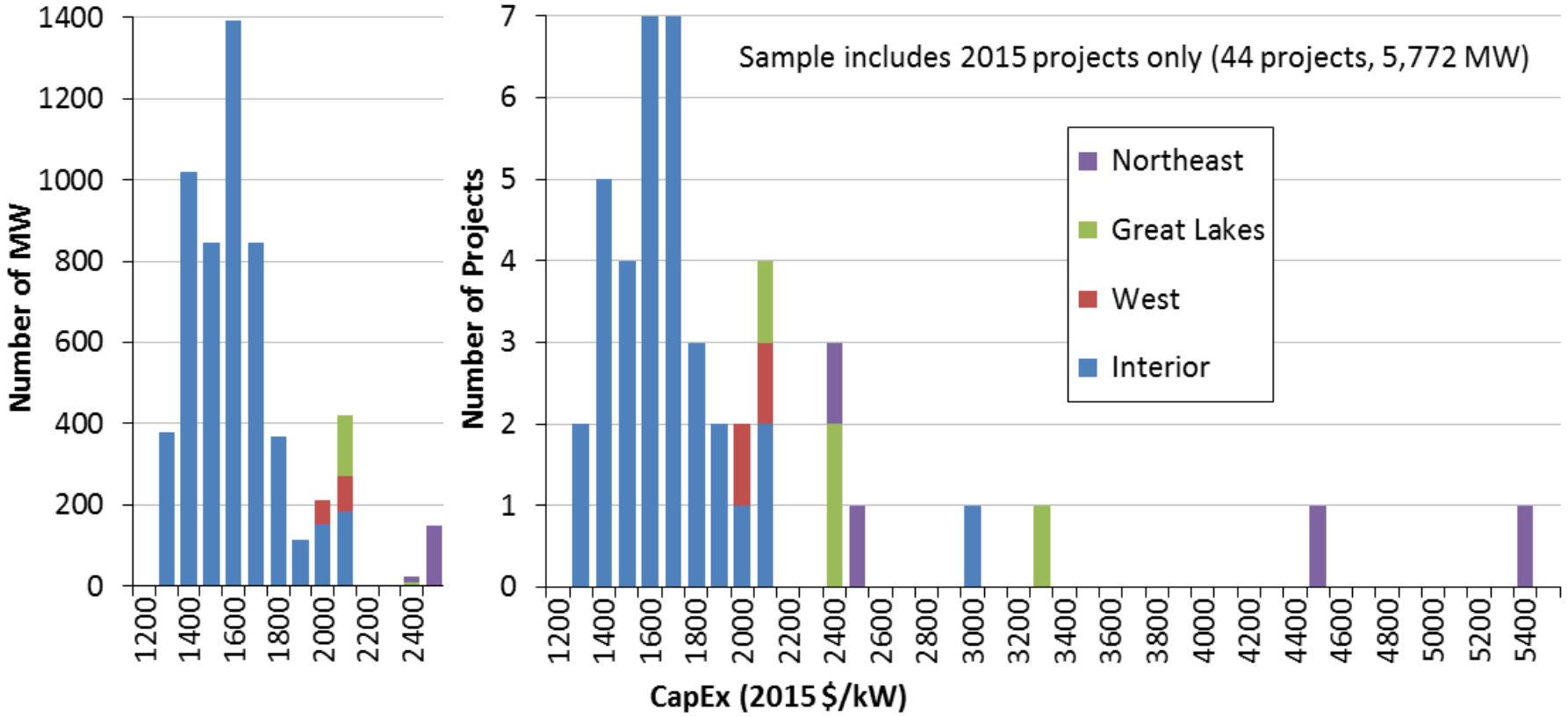


Turbine Size

Regional Differences in Average Wind Power Project Costs Are Apparent, but Sample Size Is Limited

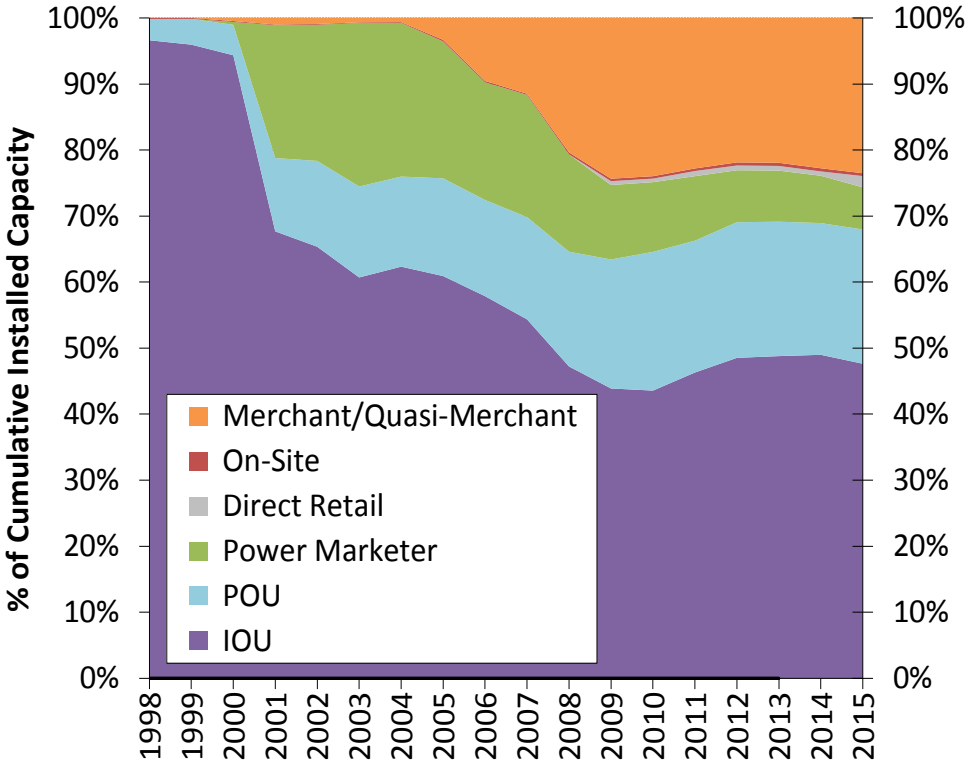


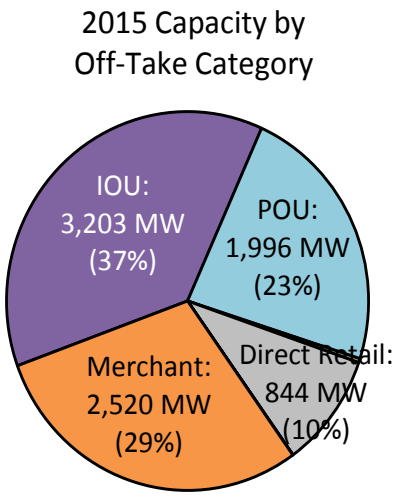
Most 2015 Projects—and All of the Low-Cost Projects—Are Located in the Interior; Other Regions Have Higher Costs



Wind Power Price Trends

Long-Term Sales to Utilities Remained the Most Common Off-Take Arrangement, but Direct Retail Sales Gained Ground



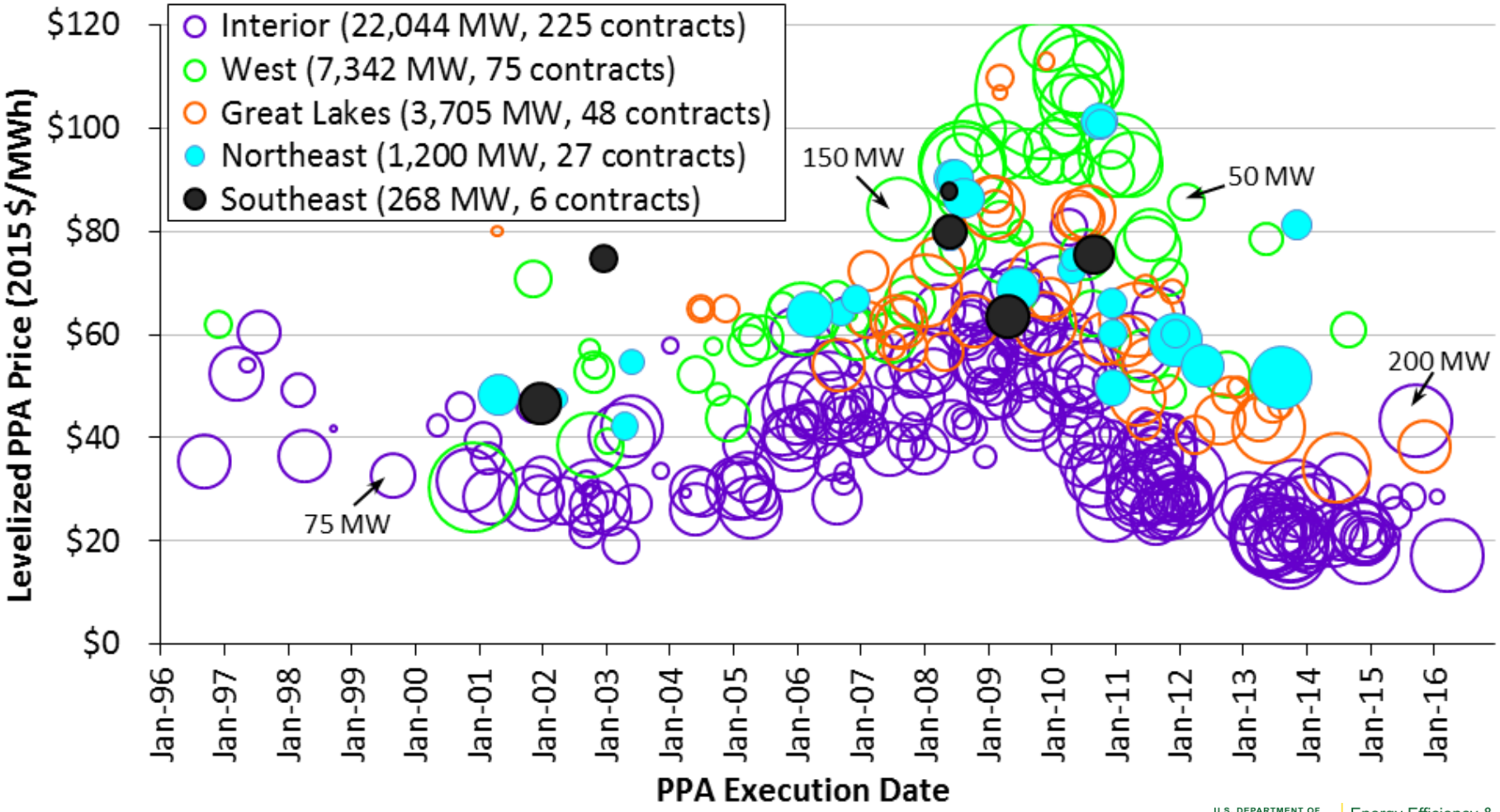


- 10% of added wind capacity in 2015 are from direct retail sales; 52% of total wind capacity contracted through PPAs in 2015 involve non-utility buyers

Sample of Wind Power Prices

- Berkeley Lab collects data on historical wind power sales prices, and long-term PPA prices
- PPA sample includes 387 contracts totaling 34,558 MW from projects built from 1998-2015, or planned for installation in 2016 or 2017
- Prices reflect the bundled price of electricity and RECs as sold by the project owner under a power purchase agreement
  - Dataset excludes merchant plants, projects that sell renewable energy certificates (RECs) separately, and direct retail sales
  - Prices reflect receipt of state and federal incentives (e.g., the PTC or Treasury grant), as well as various local policy and market influences; as a result, prices do not reflect wind energy generation costs

Wind PPA Prices Remain Very Low, Especially in Interior Region



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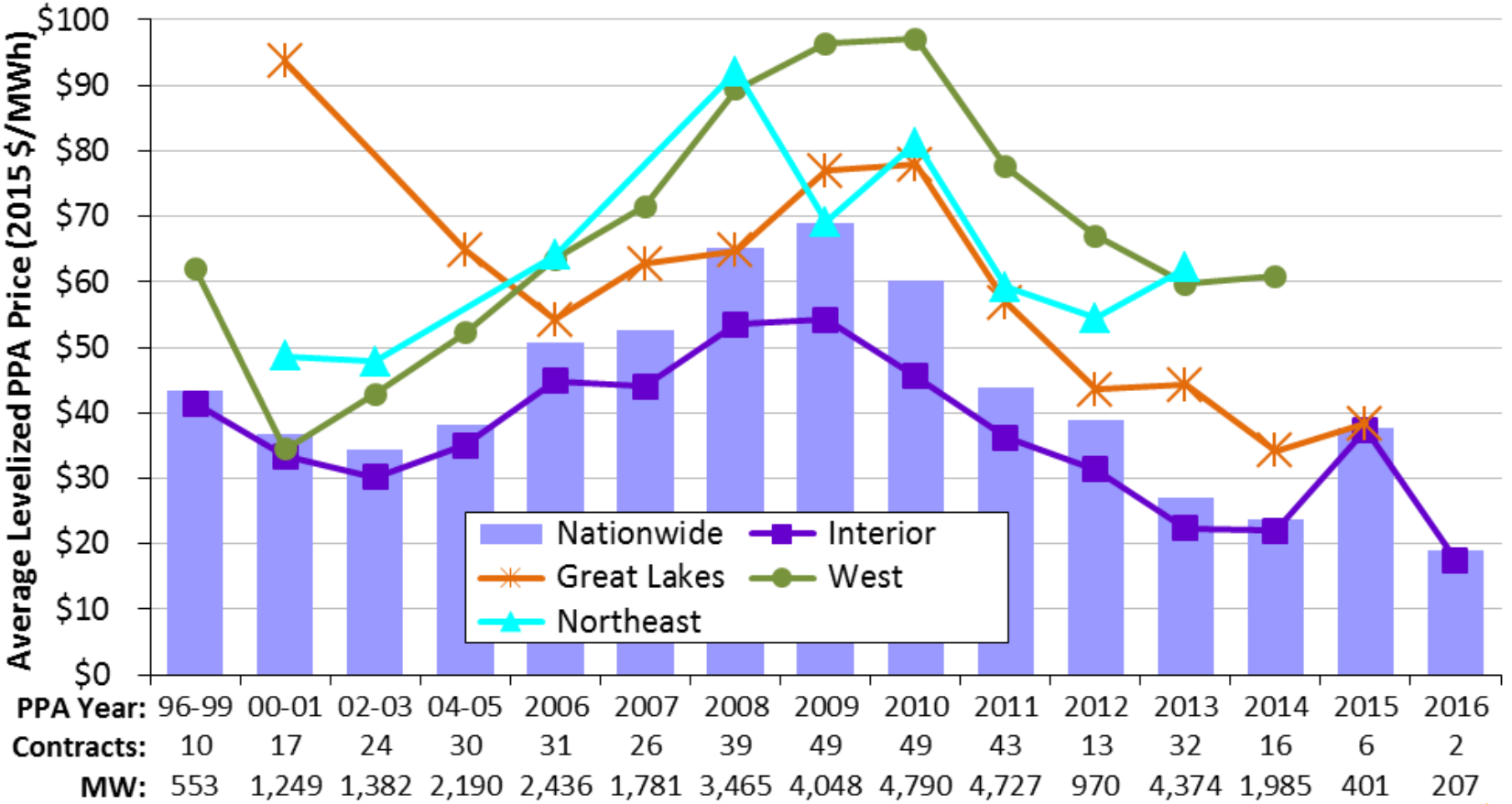
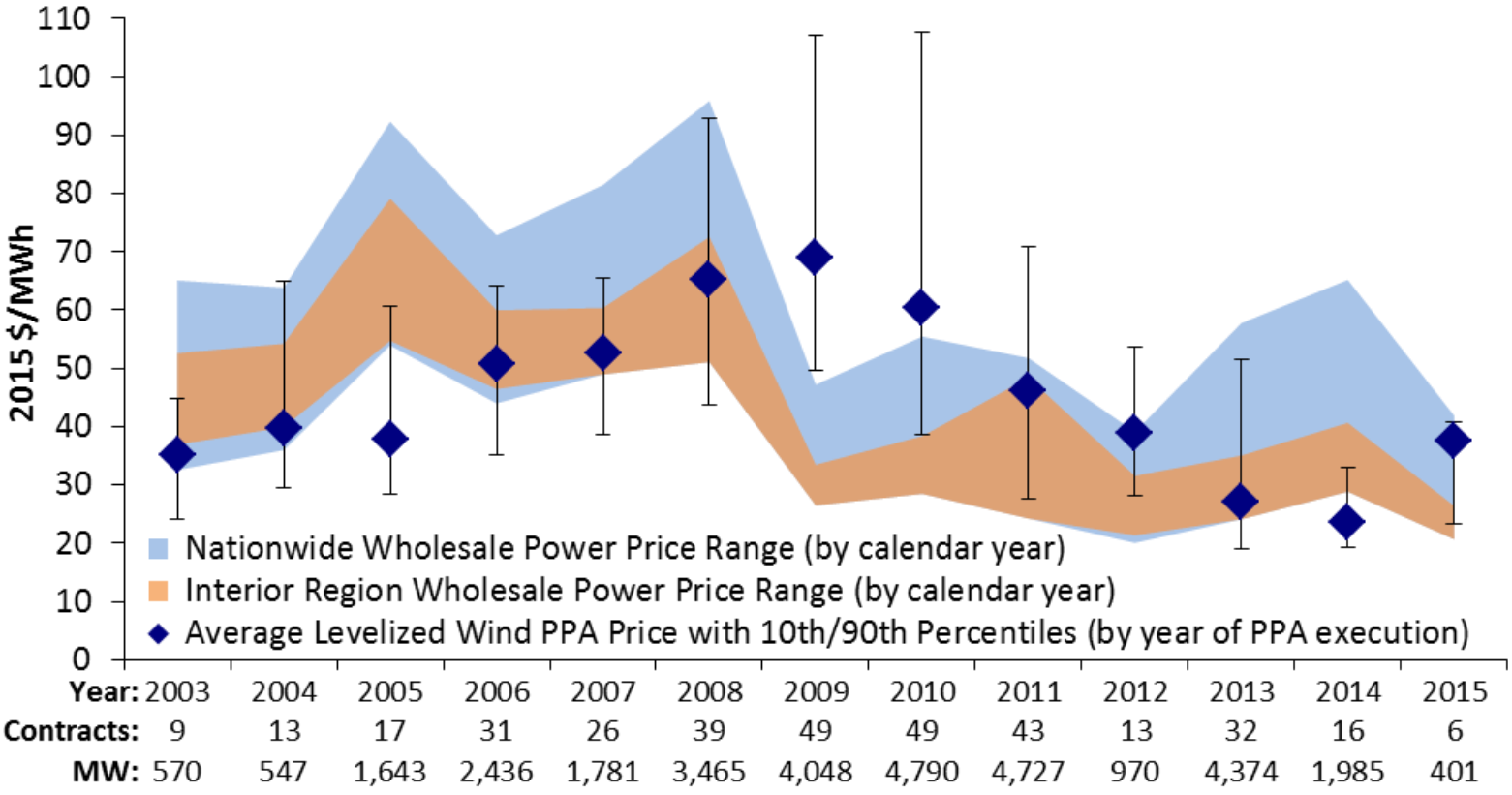
A Smoother Look at the Time Trend Shows Steep Decline in Pricing Since 2009; Especially Low Pricing in Interior Region



Relative Competitiveness of Wind Power Challenged in 2015 as a Result of Dropping Wholesale Electric Prices



- Wholesale price range reflects flat block of power across 23 pricing nodes across the U.S. (and Interior)
- Price comparison shown here is far from perfect – ***see full report for caveats***

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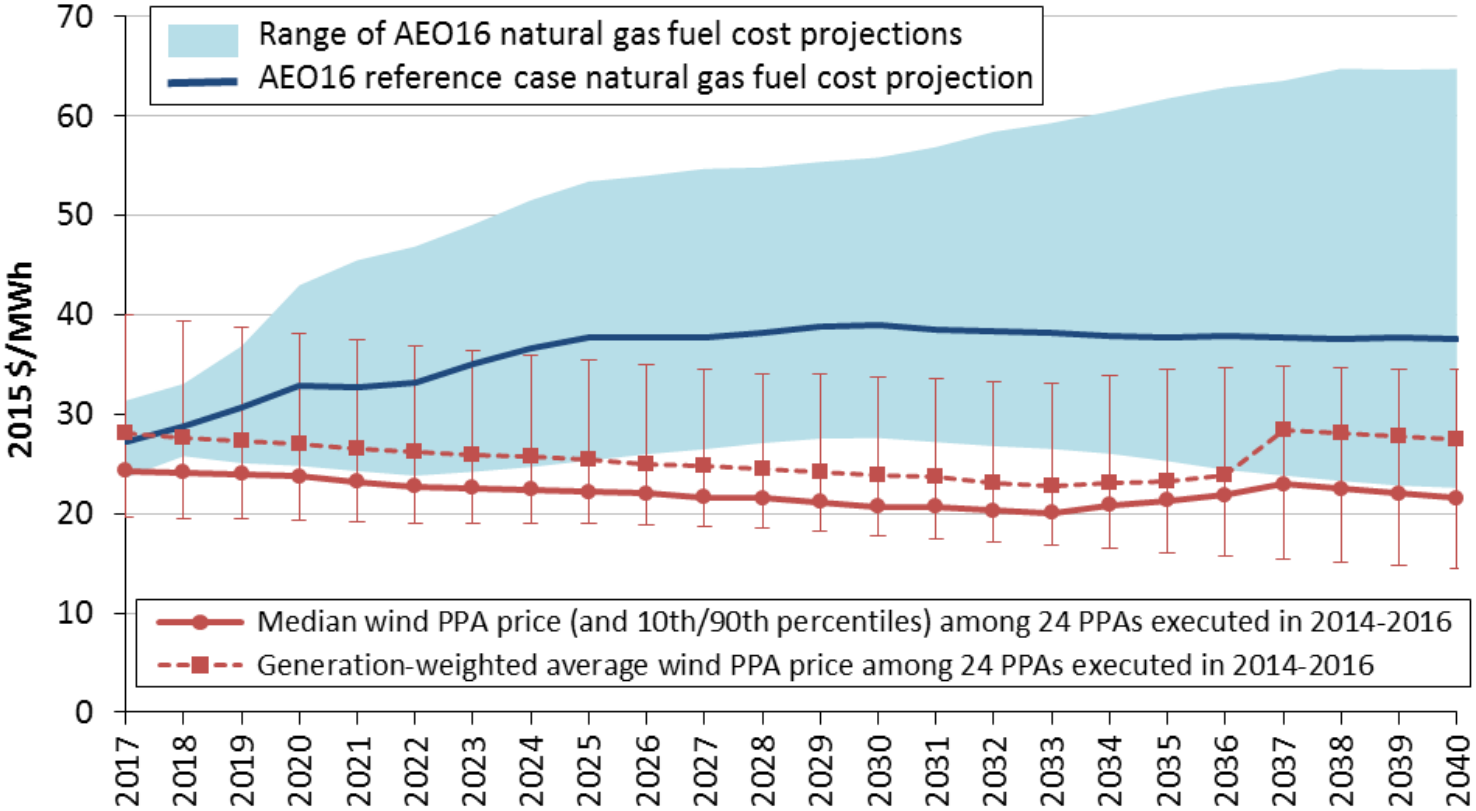
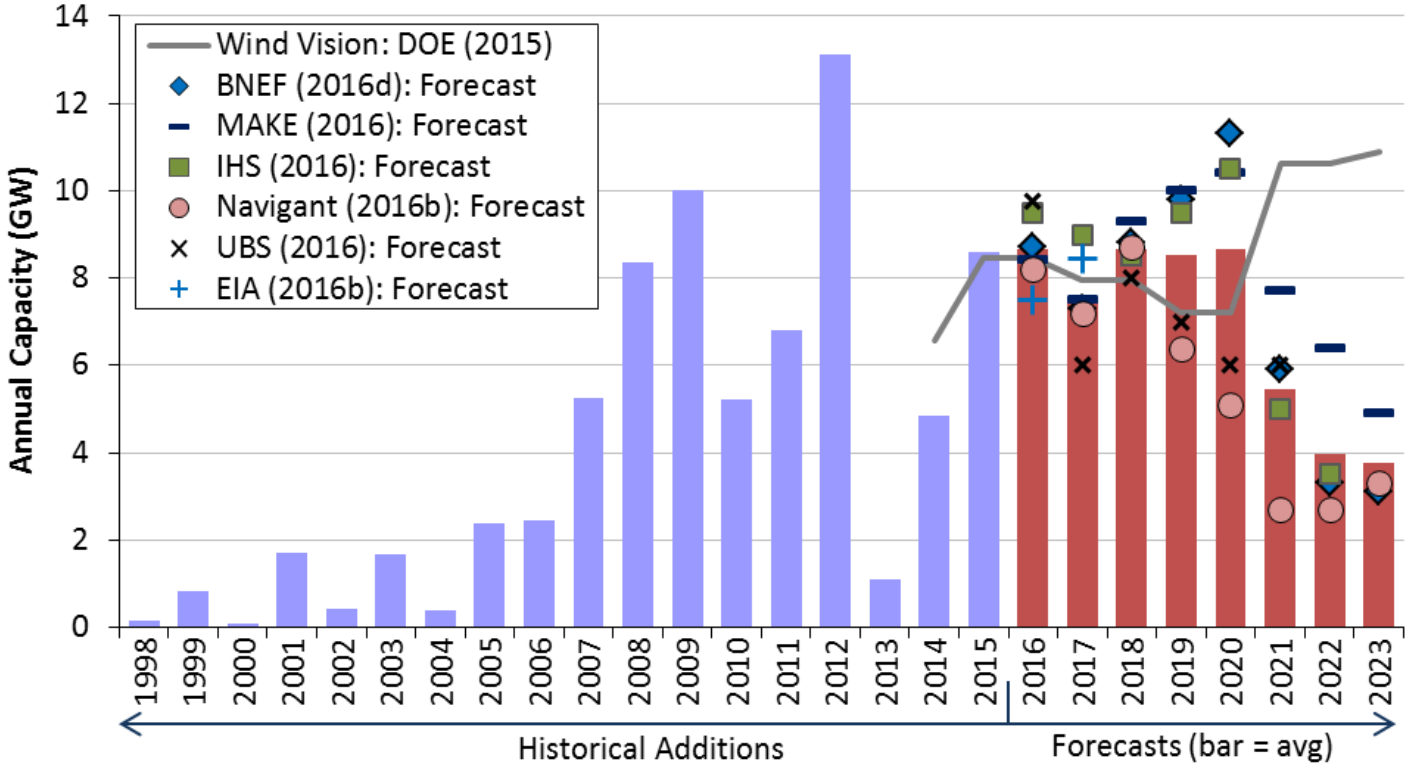
Recent Wind Prices Are Hard to Beat: Competitive with Expected Future Cost of Burning Fuel in Natural Gas Plants



*Price comparison shown here is far from perfect – **see full report for caveats***

Future Outlook

Sizable Wind Additions Anticipated for 2016-20 Given PTC Extension; Downturn and Uncertainty Beyond 2020



Wind additions through 2020 consistent with deployment trajectory analyzed in DOE's *Wind Vision* report; not so after 2020

Current Low Prices for Wind, Future Technological Advancement, New EPA Regulations, and Direct Retail Sales May Support Higher Growth in Future, but Headwinds Include…

- Phase-down of federal tax incentives
- Continued low natural gas and wholesale electricity prices
- Modest electricity demand growth
- Limited near-term demand from state RPS policies
- Inadequate transmission infrastructure in some areas
- Growing competition from solar in some regions

For More Information

For More Information...

See full report for additional findings, a discussion of the sources of data used, etc.

- http://energy.gov/eere/wind

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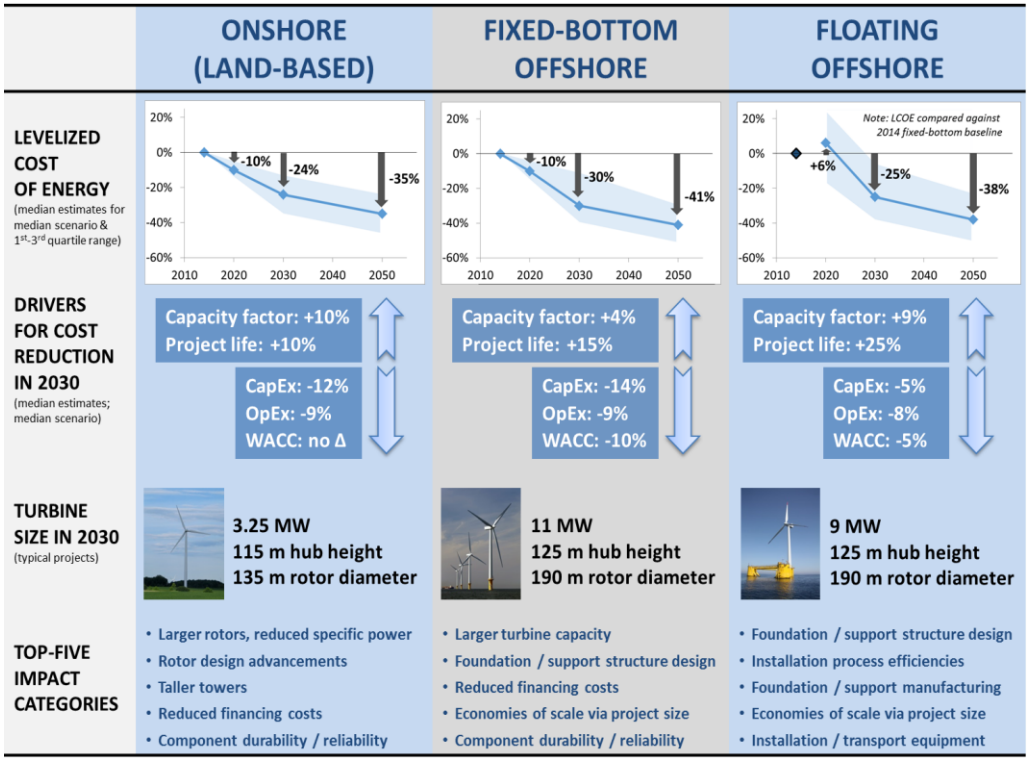
Want To Know More About the Possible Future Cost of Onshore & Offshore Wind?

Recently published expert survey of 163 of the world's foremost wind experts



Documentation:

https://emp.lbl.gov/iea-wind-expert-survey

Webinar:

September 27, 11-12 ET: https://cc.readytalk.com/r/6j3tvwsn8lto&eom